JPL STANDARD FOR SYSTEMS SAFETY

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CHANGES and REVISIONS

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Initial (Rev A)	Initial Issue	November 1988
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SECTION 1

1 POLICY AND ORGANIZATION

1.1 POLICY

The Jet Propulsion Laboratory Safety Policy and the Systems Safety Policy require safety for all personnel, and for equipment in consonance with project achievement and risk tolerance. The Systems Safety Office (SSO) is the primary organization responsible for developing and implementing the Systems Safety Policy.

JPL shall conform with all local, State, and Federal codes and regulations regarding personnel safety. Because such regulations contain "experimental" clauses, they have little constraint on experimental designs (spacecraft), but they do closely control nonexperimental ground support equipment. In addition, for international activities, JPL shall conform to the applicable international regulations and requirements specified by the nations involved for personnel safety and for hardware designs. As a minimum, JPL personnel safety requirements and management responsibilities follow JPL personnel wherever they travel.

1.1.1 Scope

This JPL Standard for Systems Safety is designed to assist managers, designers, engineers, and technicians in implementing JPL Systems Safety Policy and outside (non-JPL) agency safety requirements for their projects in accordance with the requirements of NASA Headquarters Document NPG 7120.5A, "NASA Program and Project Management Processes and Requirements," Section 4.5. Specific applications are to:

(1) Personnel working on or near JPL Critical Items. (Ref. Para. 1.7.3)

(2) JPL Critical Item components and equipment design, manufacture, and test activities.

(3) Environmental testing at all levels of assembly.

(4) Transportation and handling of JPL Critical Item hardware at all levels of assembly.

(5) Hazardous components, equipment, materials, and substances.

(6) Critical support and operational equipment.

(7) Facilities used for fabrication, assembly, inspection, test, storage, prelaunch processing, and launch.

1.1.2 Applicability

This requirements document is applicable to all JPL "in-house" tasks and projects. For the purposes of this document, "in-house" is defined as operations and activities within JPL facilities.

In addition, this document shall be used as a guideline for the evaluation of system/subsystem or other critical hardware safety programs at JPL contractors, and as appropriate at "partner" facilities. At the discretion of each project, this document may be tailored for specific contractual purposes to document systems safety requirements. The application of specific requirements contained within this document are governed by the following criteria:

(1) All projects and tasks shall meet regulatory requirements for personnel safety, and for hardware and facility safety external to the project.

(2) Safety requirements which are intended solely for the protection of project hardware or other project resources shall be implemented at the discretion of the Project Manager. The project policy shall be defined in the Project Plan and/or the Project Safety Plan. Subsequent deviations from the approved Plan shall be documented using the waiver process defined in Section 1.3.4, Waivers, Exceptions, Deviations, and Nonconformances.

(3) As a minimum, hardware valued above $100,000 shall be provided hardware protection by performing Facility, Operations, and Transportation Safety Surveys (Refer to Section 1.3.7.2). Hardware protective measures to be required are at the discretion of the cognizant manager who has ultimate authority over and responsibility for the hardware. (Refer to Section 1.2.1)

1.1.2.1 *Project*: For the purposes of this document, the term "project" includes projects, programs, experiments, and tasks, and refers to an activity for which JPL has responsibility for its successful accomplishment. Most "projects" are accomplished within the Develop New Products (DNP) domain; however, the Systems Safety Process is applicable to projects and tasks accomplished within the Develop New Technology (DNT) domain.

1.1.2.2 *Project's System:* For the purposes of this document, the term "project's system" refers to critical or support hardware, equipment, and/or facilities for which the project is solely responsible. This means that losses due to failures or incidents within the Project's system would have no impact on other projects or activities, or to common use or shared resources or facilities.

1.1.2.3 *Project Manager*: For the purposes of this document, the term "Project Manager(s)" includes project, program, experiment, and task managers, and refers to that individual who has the JPL responsibility for its successful accomplishment.

1.1.3 Conflict Resolution.

Resolution of any conflict between specific requirements contained in this document and any other requirements shall be coordinated by the Systems Safety Process Owner.

1.1.4 Process Owner

This JPL Standard for Systems Safety document is under the control of the Systems Safety Process Owner, Manager of the Systems Safety Office (516), Safety and Mission Assurance Office (510), of the Office of Engineering and Mission Assurance (500). Suggestions for changes shall be submitted and evaluated as specified in Section 1.5.

1.2 ORGANIZATIONAL RELATIONSHIPS

1.2.1 General Safety Responsibility

Project Managers, engineers, designers, and test personnel shall apply safety practices and requirements to assure a safe and successful mission. They should consult with the assigned Systems Safety Engineer (SSE) on specific issues or regulatory environments.

The responsibility for safety is established by published JPL Role Statements and is summarized as follows (Fig. 1.2-1):

The responsibility for systems safety policy, processes, and process procedures rests with the Systems Safety Process Owner.

The responsibility for the establishment, maintenance, and enforcement of safe working conditions and operating procedures rests with line management.

Section Managers (and Section-level managers) serve as the primary line management individuals responsible for ensuring the safety of personnel, equipment, and facilities assigned to the section at JPL and at off-site locations. Section Level Managers cannot delegate this responsibility. This responsibility includes certifying to the safety of all hardware fabricated or procured under the cognizance of their section. (Refer to Safety and Health Plan, Para. M)

Project Managers plan, direct, and control all activities required to attain project objectives in accordance with the Program/Project Plan, or Implementation Plan, and consistent with all policies, practices, standards, and procedures of JPL and NASA as applicable. They are also directly responsible for the safety of hardware or software which is procured by the project without the support of a technical section or cognizant engineer. The Project Manager's authority may be delegated through the System and/or Instrument Managers and the Project Element Managers (PEMs). The overall responsibility remains with the Project Manager. Project Managers are responsible for assuring the generation and implementation of project safety plans. The assigned SSE is available for support.

Cognizant Engineers are accountable to the project and/or to line management for safety affecting their hardware and/or software and/or service, depending on the specific project organization. In all cases, they must report safety-related matters to section management and/or the Project Element Manager.

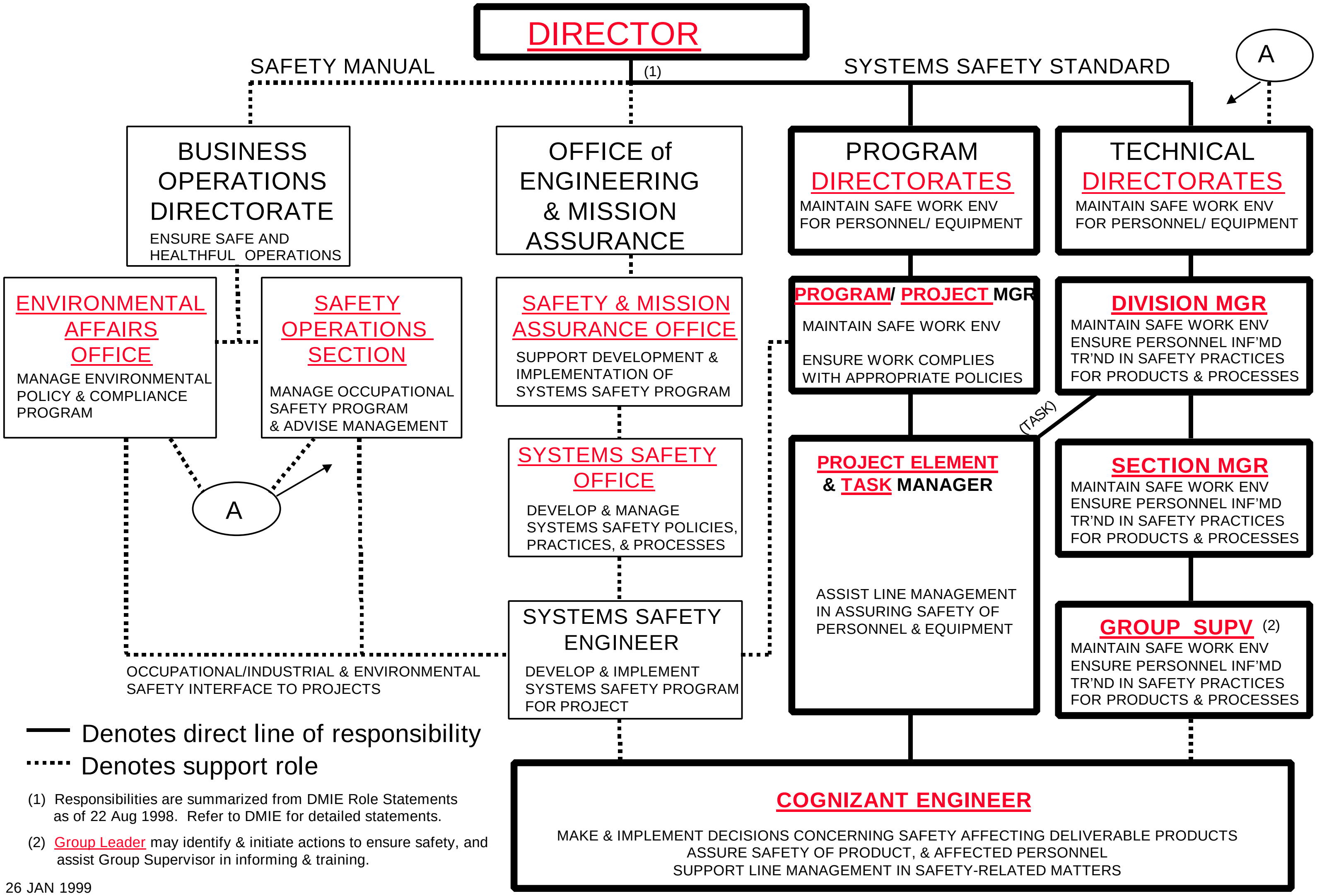
Individual employees are responsible for adherence to safety requirements, for the implementation of good practices and techniques, and for reporting to their supervisor any condition, existing or anticipated, that they consider hazardous.

The Systems Safety Engineer shall determine the applicability of regulatory requirements by assessing the potential for personnel injury, or for equipment/facility damage outside of the project's system. The Systems Safety Engineer shall advise the Project Manager regarding the applicability of requirements intended solely for the protection of equipment within the project's system. The Project Manager has the authority to implement those requirements based on schedule and/or cost risk to the project.

The Systems Safety Engineer shall report directly to the Project Manager and is the Project Manager's agent in overseeing the Project's safety activities. The Project's organization shall be documented in the project Safety Plan (Ref. Para. 1.3.1). Day-to-day interaction shall be accomplished at the appropriate working level.

A working relationship shall be established between the Product or Mission Assurance Manager (PAM/MAM) and the Systems Safety Engineer to implement a cost effective periodic and case-by-case reporting chain appropriate for the individual project for safety related matters (Fig 1.2-2).

Figure 1.2-1: SAFETY RESPONSIBILITIES ON PROJECTS



NOTE: Double-click to activate slide, then pointto activate desired hyperlink for Charter or Role Statement.

SYSTEMS SAFETY AND MISSION ASSURANCE INTERACTIONS

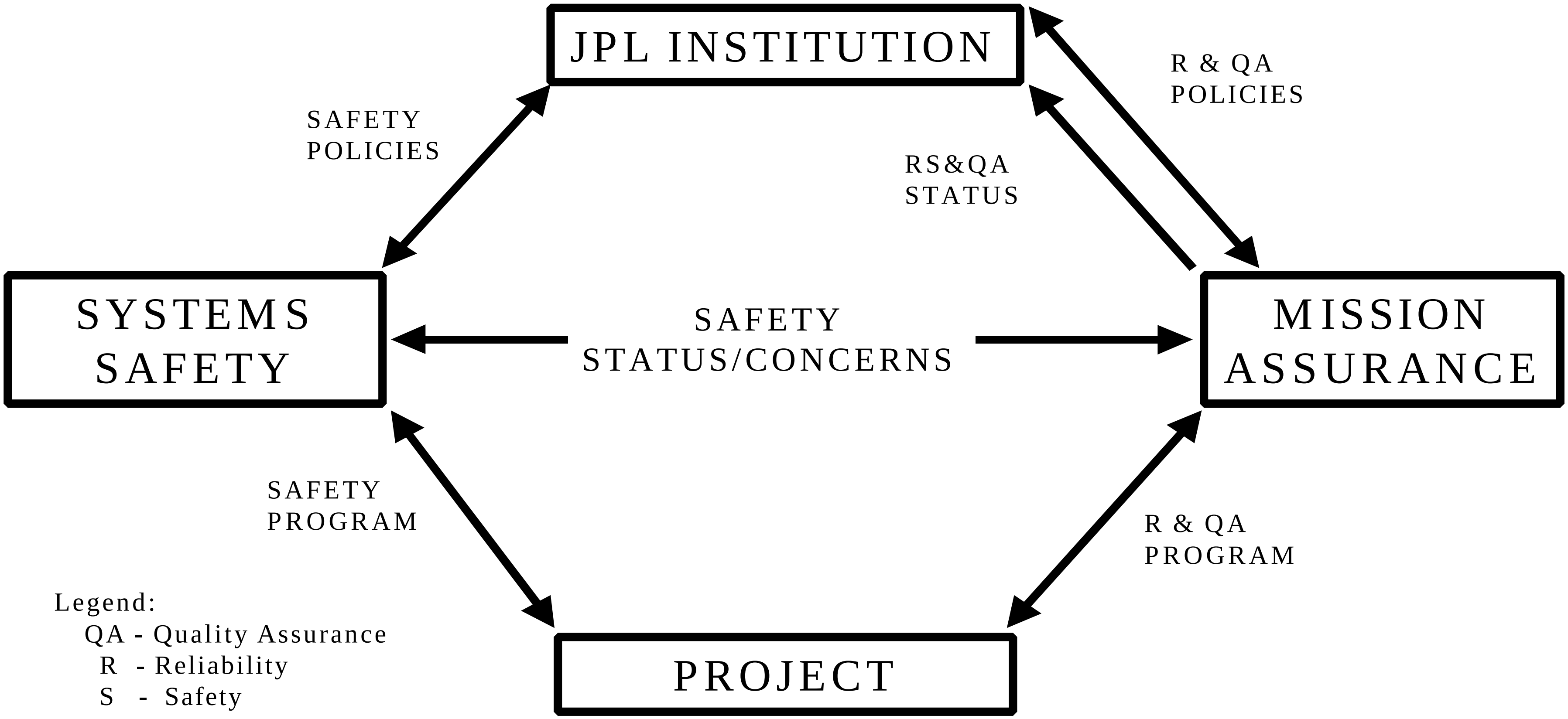


Figure 1.2-2 Systems Safety / Mission Assurance Working

1.2.2 Specific Organization Responsibilities in Safety Support of Projects

The **Systems Safety Office** is concerned with system failures or mishaps, defined as failures or mishaps that have the potential for injury to people, or for causing consequential damage to property external and internal to the system. In this context, the term system refers to all flight and ground equipment including software, procedures and operating personnel comprising the particular project or task.

The **Systems Safety Office** fulfills two types of roles. One is regulatory in the sense that the **SSO** inputs of issues and concerns to a Project/Task Manager must be acted upon by the Project Manager as a matter of Lab policy. The other is advisory and does not require, as a matter of Lab policy, action by the Project/Task Manager.

The **Systems Safety Office** has a regulatory role with respect to the potential of the given system for causing injury to persons or causing damage to property external to the environment of the system or to the general environment including hazardous waste.

The **Systems Safety Office** has an advisory role with respect to the potential for damage to equipment that is part of the system. This is irrespective of whether the potential for damage is the result of equipment, handling procedures, or personnel, and whether the threat arises from sources external or internal to the system.

The **Systems Safety Office** has the responsibility for fully apprising the Project Manager, early in the project/task-planning phase and continually throughout the life cycle phase, of any and all regulatory safety requirements.

In all cases the Project Manager has sole responsibility and sole accountability for any and all preventive measures and corrective actions. The **Systems Safety Office** will advise the Project/Task Manager on the appropriateness and effectivity of such actions. The Project/Task Manager may delegate authority through the Project Safety Plan to the Systems Safety Engineer for implementing and/or directing specific project/task responsibilities.

With respect to the regulatory inputs from the **Systems Safety Office**, the Project/Task Manager's response is governed by the appropriate safety requirements. Deviations to those requirements require appropriate waiver approval.

With respect to advisory inputs, the response is totally at the discretion of the Project/ Task Manager.

1.2.2.1 ***Systems Safety Office Charter****:* The **Systems Safety Office (SSO)** is the primary organization for developing and implementing the Laboratory's Systems Safety Programs. The major responsibilities of the **SSO** staff are defined in JPL Charter "Systems Safety Office--516" and are repeated below for reader convenience. In case of differences, the latest version of the Charter is the controlling document. (Following text from April 27, 1998 Official version:)

> The major responsibilities of this office are to manage the Laboratory's Systems Safety activities by developing, coordinating and issuing system safety policies, standards, procedures, and practices and to assist and assess the Laboratory and Laboratory programs/projects/tasks in the application of these issuances.

Charter:

Specific activities include:

(1) Evaluate and establish as appropriate the implementation of system safety programs for the development of new products or technologies and all programs, projects, and tasks under the cognizance of the Mars Program Office, Space and Earth Sciences Directorate, the Technology and Applications Program Directorate, and the Tracking and Missions Operations Directorate.

(2) Appoint, with Program/Project/Task Manager approval, qualified System Safety Engineer(s) to develop and implement the Project/Task Systems Safety Program.

(3) Review and analyze Program/Project/Task hardware design and software development, test and operations for compliance with JPL, customer, and launch agency safety requirements and regulatory/code requirements affecting safety of personnel, facilities, and adjacent systems and recommend to management appropriate mitigation actions.

(4) Advise Program/Project/Task management on safety issues with potential legal ramifications involving interactions with external organizations.

(5) Support program/projects and tasks in the systems safety requirements tailoring process to assure compliance with Laboratory, NASA, DOD, and other agency regulatory safety standards.

(6) Generate and coordinate program/project/task safety items associated with product delivery, safety interfaces, payload integration, and safety reviews with launch vehicle providers, launch agencies, contractors, other NASA Centers, and other regulatory agencies.

(7) Support Project/Task Managers by co-chairing and a dministering Program/Project/Task Safety Steering Committees.

(8) Monitor and participate in reviews of JPL program/project/task critical software or critical equipment assembly, test, transportation, and operations procedures at the Laboratory, JPL Contractors, test and launch sites.

(9) Conduct safety surveys to assess program/project/task critical hardware and operations interfaces with current or proposed facilities and advise cognizant engineering, supervisory and management personnel of safety issues that could jeopardize personnel, equipment, or facilities.

(10) Review as specified in the Project Implementation Plan the safety aspects of procurements, analyses, plans, procedures, standards, waivers, Engineering Change Requests (ECRs), Problem/Failure Reports (P/FRs) and hazardous operations to assess safety risk and liability, and recommend risk reducing solutions to Program/Project/Task management as appropriate.

(11) Maintain insight into JPL contractor's system safety program development and implementation activities, assist/advise in preparation of safety compliance documentation, conduct of hazard analyses, or proactive safety surveys, and advise program/project/task management on potentially deficient areas or increased safety risks.

(12) Participate in all accident investigations involving flight and other critical hardware.

(13) Notify cognizant Laboratory supervisory and management personnel of safety issues that could jeopardize their personnel or equipment and stop such activities that present an imminent danger.

(14) As the project/task safety representative, work in consonance with the Safety Operations Section, the Environmental Affairs Office, Facilities and other cognizant Divisions, and the Launch Approval Planning Group to resolve matters of common concern pertaining to project/task safety of personnel, equipment, facilities or the environment.

(15) Function as the JPL focal point for systems safety interactions and document review with NASA Headquarters, NASA Centers, other government agencies, and contractors.

(16) Function as a member of the Laboratory Safety Committee, Structures and Materials Review Committee (SAM-RC), and JPL project/task safety committees or safety working groups.

(17) Develop, coordinate, and issue JPL system safety policies, standards, procedures, and practices.

(18) Perform other such duties as the Manager of the Safety and Mission Assurance Office may assign.

1.2.2.2 *Systems Safety Office Roles:* The Systems Safety Office (SSO) assists in the development and evaluation of safety practices, and shall act as a team member with the project manager in areas such as:

(1) Establishing systems safety design and operational requirements for the project commensurate with applicable safety standards, government codes, and other safety documents.

(2) Fostering safety reviews and/or safety analyses on project-associated equipment to detect hazards that may exist to personnel or to equipment.

(3) Coordinating directly with launch vehicle providers, launch agencies, other NASA centers, and other regulatory agencies for safety items associated with safety interfaces, payload integration, and planned safety reviews.

(4) Maintaining an overview of project safety activities.

(5) Evaluating test and operating procedures for safety.

(6) Recommending additions or changes to the JPL Safety Manual.

(7) Evaluating all changes to equipment or procedures that affect the hazardous aspects of the equipment.

(8) Establishing requirements for any necessary supporting safety analysis.

(9) Generating and maintaining the hazard reports or listings and safety data.

(10) Reviewing, coordinating, and supporting safety requirements with the cognizant NASA Program Office.

(11) Participating in design, project, test readiness, preship, and prelaunch reviews.

(12) Co-chairing and administering the Safety Steering Committee and bringing to the Safety Steering Committee the safety experience of other JPL project activities.

(13) Prior to contract award, providing proposal review and safety inputs for procurements from contractors.

(14) During contract performance, reviewing contractor safety documentation and safety coverage (with contract negotiator or project manager concurrence) and advising Project and the contractor's cognizant engineers of any safety concerns.

(15) Communicating to project management and technical organizations technical safety status, concerns, and issues. Communicating to the Mission Assurance Manager non-technical safety performance.

(16) Supporting the Project Office in the development of the Safety Plan.

(17) Providing burden funding for those activities that are review and oversight of the project.

(18) Interfacing between all Project activities and other JPL organizations, such as the Occupational Safety Office and the Environmental Affairs Office, for safety related matters.

1.2.2.3 *Project Office:* The Project Office shall be responsible for the following safety related functions:

(1) Providing a safe working environment and equipment designs.

(2) Supporting NASA in obtaining required safety approvals where other governmental agencies are involved.

(3) Being cognizant of safety requirements to assure activities and equipment designs conform to requirements.

(4) Certifying the safety of project hardware to outside agencies.

(5) Providing funding for those safety activities that are in direct support of the project or produce a product for the project.

1.2.2.4 *Mission Assurance Office:* The Mission Assurance Office shall be responsible for the following safety related functions:

(1) Accounting to the project office for safety personnel performance and non-technical issues/concerns.

(2) Ensuring that safety has a direct line of communication to the Project Manager as shown on organization charts.

(3) Ensuring appropriate safety review of P/FRs, ECRs, waivers, and other documents for safety concerns.

1.2.2.5 *Quality Assurance Office:* The Quality Assurance Office shall be responsible for the following safety related functions:

(1) Participating in Facility, Operations, and Transportation Surveys. Verifying open item completion prior to initiation of activities.

(2) Implementation and conduct of Electrostatic Discharge (ESD) Surveys.

(3) Day-to-day oversight of safety requirements implementation by the doing organizations.

(4) Safety item closure inspections, test observations, and closure documentation.

(5) Notification to the **Systems Safety Office** of non-compliant safety activities.

1.2.2.6 *Technical Section Level Offices:* Section Level Offices shall be responsible for:

(1) Serving as the primary management responsible for maintaining a safe work environment for all personnel.

(2) Ensuring that section personnel are informed and trained in safety practices for products and processes.

Group Supervisors within Technical Sections shall be responsible for:

(3) Ensuring that section personnel are informed and trained in safety practices for products and processes

1.2.2.7 *Safety Steering Committee*: A Safety Steering Committee shall be established for each JPL in-house Project (See Section 1.1.2 for applicability.) The membership of the Safety Steering Committee shall involve the Project Manager, Project Element Managers and/or Cognizant Engineers /Contract Technical Managers, and/or those Section Managers (or equivalent) having line safety responsibility for any operations or activities which include design, manufacture, fabrication, assembly, test, transportation, prelaunch, launch, and on-orbit activities, entry, abort, and post flight operations of both flight and ground hardware. The **SSO** has the prerogative to recommend additional members to the Committee as deemed necessary and appropriate (i.e.: Radiation Specialists, Transportation Consultants, etc.).

A Section Manager may appoint an alternate to represent him/her on the Committee if he/she so desires (e.g.: Technical Manager or Assistant Section Manager), but in compliance with the JPL Safety Manual, the Section Manager's safety responsibility cannot be delegated. The degree of the Section Manager's participation in the Committee should be commensurate with the hazards associated with the activity for which he/she is responsible.

The Project Manager shall co-chair the SSC, along with the Systems Safety Engineer. If the project is sufficiently large, an Office Manager specifically responsible for the system design and reporting directly to the Project Manager may co-chair the committee in lieu of the Project Manager. This option requires concurrence of the Project Manager and the Systems Safety Office Manager.

1.2.2.7.1 Committee Responsibilities: The Safety Steering Committee shall carry out the following duties:

(1) Review and approve the applicability of safety requirements for the project.

(2) Review the identified hazards associated with the flight hardware, software, and GSE (electrical and mechanical) design for completeness and accuracy.

(3) Evaluate techniques for minimizing or safely accommodating the hazards that cannot be eliminated.

(4) Review hazard-related interfaces involving the launch vehicle (including STS, ELV, upper stages, etc., as appropriate), ground equipment, handling equipment, launch complex, software, special nuclear materials, etc.

(5) Review hazard reports and safety packages prepared for transmittal to outside agencies such as KSC, launch agency, etc.

(6) Evaluate appropriate test and operations schedules and sequences to assure personnel safety and appropriate equipment safety.

(7) Review design changes that have safety implications and concur that changes are acceptable from a safety standpoint.

1.2.2.7.2 Chairperson Responsibilities: The chairpersons of t he Safety Steering

Committee are responsible for:

(1) Organizing and conducting Safety Steering Committee and associated meetings.

(2) Assigning action items or tasks to the members of the committee or other project personnel, as necessary, to carry out committee functions.

(3) Assuring that the committee work is carried out in a timely and effective manner.

1.2.2.7.3 **SSO** Representative Responsibilities: The **SSO** representative to the Safety Steering Committee is responsible for:

(1) Supporting and advising the chairman in organizing meetings to carry out the duties of the committee.

(2) Assessing safety concerns regarding the interfaces between hardware, software, and/or equipment elements.

(3) Acting as advisor for the committee's activities in evaluating safety.

(4) Coordination of Safety Steering Committee activities with the JPL Safety Committee and other JPL groups such as the Radiation Safety Committee, the Structures and Materials Review Committee, etc.

(5) Acting as consultant to the committee on safety matters, i.e. policy requirements, standards, etc.

(6) Suggesting areas for committee evaluation and subjects for consideration.

1.2.2.7.4 Frequency of Meetings: A meeting shall initially be held to organize the committee and initiate the activity of hazard reporting. When the state of the conceptual or preliminary hardware design is appropriate for committee review, i.e., PDR, meetings shall be held until the review of all safety concerns of the project are complete and appropriate actions are completed. If the design has no impact on the safety of the personnel, hardware, or STS or other launch vehicle safety, then only a single meeting is required to ascertain that no hazards exist.

Where the hardware design is substantially the same as on previous missions, but there is a significant change of involved personnel, the Project Manager shall determine the scope of safety committee meetings necessary to assure that proper safety requirements are understood by all personnel. After the initial review, meetings shall only be convened as warranted by specific safety concerns. In the interest of effective, efficient safety reviews and evaluations, only the minimum number of committee members shall convene as needed for consideration of specific subjects.

1.3 DOCUMENTATION

1.3.1 Safety Plan

A Safety Plan is required for each project built by JPL or contracted for or provided outside of JPL. A Safety Plan is also required for each system, subsystem, instrument, or experiment contracted for by JPL as part of the project. Safety Plans for high level assemblies such as projects and systems shall cover any sub-assemblies or lower level items that they contain. The Project Manager shall assure an appropriate plan is developed. The Safety Plan Completion Schedule shall be as specified by the project or task milestone schedule. It shall be developed during the formulation phase and implemented by the beginning of the implementation phase. The Safety Plan shall be applicable through the entire life cycle of the project.

The Safety Plan shall assure adequate safety to personnel, flight hardware, and ground support equipment. The safety considerations shall include storage, assembly, inspection, handling (including shipping and transportation), test, and operations being or to be conducted in all facilities (contractor, subcontractor, JPL, other NASA centers, university, or others). In general, the Safety Plan shall be in keeping with the complexity and risk tolerance of the project and shall clearly specify the level and scope of hardware safety to be implemented on the project. The plan shall include, as appropriate:

(1) Introduction.

(2) Applicable Documents.

(3) System Safety Program (Including description of or reference to the Occupational/Industrial Safety Program).

(4) Project Organization.

(5) System Safety Schedules.

(6) System Safety Requirements.

(7) Preliminary Hazard Analyses.

(8) System Safety Data.

(9) Hardware Protection.

(10) Software Safety.

(11) System Safety Assurance.

(12) Training.

(13) Audit Program.

(14) Mishap Reporting and Investigation.

(15) System Safety Interfaces.

1.3.2 Safety Data Package

Ground processing and in-flight hazards shall be identified as appropriate for the project. Data package formats and contents are usually defined by the specific operations or launch site. (See Section 1.3.2.1 or 1.3.2.2 for U.S. launch vehicles).

Hazards which should be addressed and methods of mitigation documented include, but are not limited to, the following:

(1) Flammables in hazardous quantity.

(2) Toxic materials (beryllium metal and dust, solvents, mercury, etc.).

(3) Propellants.

(4) Ordnance (solid rocket motors, pyrotechnics, etc.).

(5) Voltages above 30 VDC or 30 VAC RMS (50 V if equipment is used only at JPL).

(6) Pressurized systems.

(7) Mechanisms/energy storage devices (springs, tensioned cables, etc.).

(8) Batteries.

(9) Asphyxiants (nitrogen, helium, argon, neon, xenon, etc.).

(10) Temperature extremes.

(11) Cryogenic fluids (LN_2, LH_2, LHe, LOX, solid $C0_2$ and H_2, etc.).

(12) Corrosives.

(13) Rotating equipment.

(14) Ionizing and nonionizing radiation sources (RF, laser, ultraviolet, or high intensity light, x-ray, microwave, nuclear, etc.).

(15) Any other item that may be a hazard.

1.3.2.1 *Hazard Reports (STS):* For missions utilizing the STS, hazard reporting shall conform to the requirements and procedures described in NSTS 13830, "Payload Safety Review and Submittal Requirements".

1.3.2.2 *Hazard Reporting (ELV):* For missions utilizing expendable launch vehicles (ELV), hazard analysis and reporting formats shall conform to specific launch area requirements, or as negotiated with all elements involved in the launch vehicle integration and launch process. NASA Document NASA STD-8719.8, "Expendable Launch Vehicle Payload Safety Review Process Standard ," or equivalent, shall be used as a guideline and tailored to suit the specific mission.

1.3.3 Drawings and Documentation.

Safety-related information shall be included in engineering documentation:

1.3.3.1 Hazardous Items. Drawings, procedures, or other design documentation for items or assemblies which present hazards to personnel, equipment, or facilities shall bear appropriate notification of those hazards. Examples of such hazards are, but are not limited to:

(1) Hot or cold surfaces.

(2) Explosive materials and devices.

(3) Corrosive or otherwise hazardous chemicals and vapors (such as battery fluids).

(4) Toxic or flammable substances.

(5) Radioactive materials.

(6) Other radiation producing devices or processes, such as x-ray, microwave, ultrasonic equipment, laser, ultraviolet, or other high intensity light sources, and high acoustic levels.

(7) Pressure vessels or pressurized systems or devices. (See Sections 2.7 and 3.6 for specific information.)

(8) Hazard-proofing status (especially its nonexplosion -proof status if the item is intended to be used with explosion -proofed equipment, or in potentially explosive environments).

1.3.3.2 *Items Subject to Degradation:* Design documentation and procedures for items which are subject to degradation or other hardware damage stemming from personnel, other equipment, or environmental factors shall bear appropriate notification of these vulnerabilities. Examples of hazards leading to degradation include, but are not limited to:

(1) Electrostatic discharge (potential damage to electronic devices; fire or explosion).

(2) Linear or angular accelerations.

(3) Vibration.

(4) Moisture or humidity.

(5) Chemical or solvent vapors, off-gassing or vacuum out-gassing of lubricants, liquids, or solids.

(6) Fingerprints.

(7) Substances or items which can damage surfaces.

(8) Magnetic fields.

(9) Sun or other intense light.

(10) Temperature extremes or variations.

(11) Rough handling.

(12) Radiation (electromagnetic or ionizing).

(13) Acoustic.

(14) Flammability.

1.3.4 Waivers, Exceptions, Deviations, and Nonconformances.

Requirements specified in this JPL Standard for Systems Safety may be waived/ excepted or deviated from in accordance with JPL Policy: Waivers when alternate methods are employed to achieve the required protection and the risk of injury to personnel or loss of or damage to hardware is acceptably low. Waiver approval authority rests only with the management authority that established the requirement.

Waiver requests for requirements other than those specified in this document shall be reviewed by the Systems Safety Engineer and assessed for safety risk as specified in the following paragraphs.

1.3.4.1 *Procedure:* All waivers shall be documented as specified in the System Procedure; Waiver Requests using forms JPL 1993-S or JPL 1994-S for Category A or Category B waiver requests, respectively. Waivers and exceptions shall be approved, or reviewed and risk rated, by the Systems Safety Engineer. Waivers which have a safety impact, i.e.: those having a risk assessment greater than "Negligible," shall have a written, independent risk assessment completed by the Systems Safety Engineer and attached to the waiver request before it is routed for approval. This risk assessment shall identify issues associated with the risk(s) and assess their significance .

For external requirements, the Systems Safety Engineer prepares the waiver request using the format specified by the external organization prior to its submittal to the approving authority (Para. 1.3.4.3).

1.3.4.2 *Waiver Risk Assessment Criteria:* The Product Assurance or Mission Assurance Manager for the project preparing the waiver is responsible for initiation and verification of accomplishment of the waiver risk assessment in a timely manner that supports the waiver approval routing schedule. Each waived requirement shall be assessed for risk according to Waiver Risk Assessment Criteria in Table 1-1. The overall Risk Rating is the combination of the Consequence rating and the Probability of Occurrence rating.. The waiver approval routing is dependent upon the overall risk rating as specified in Table 1-2.

1.3.4.3 *External Requirements:* Waivers to requirements imposed upon JPL by external organizations (launch agencies, etc.) shall be initiated by the Systems Safety Engineer, routed to the Project Manager for concurrence, and forwarded to the external organization for approval.

Table 1-1 Waiver Risk Assessment Criteria

				LIKELYHOOD OF OCCURENCE				
				NEGLIGIBLE	LOW	MODERATE	SIGNIFICANT	HIGH
		PERSONNEL SAFETY	**HARDWARE SAFETY**	No determinable increase in potential	Possible or slight increase in potential	Definite increase in potential	Fair possibility	Fair probability or likely
CONSEQUENCE	**CATASTROPHIC**	Potential of permanent disability or death. Injury resulting in admission to health care facility.	Major damage, complete loss of hardware, or would require salvage or complete reconstruction. Cost Estimate => $100,000	**NEG**	**LOW**	**SIG**	**CAT**	**CAT**
	SIGNIFICANT	Injury/illness requiring attention of health care facility. Lost time.	Damage repairable but definite impact to project schedule or resources. Cost estimate =>$10,000 and <$100,000	**NEG**	**LOW**	**MOD**	**SIG**	**CAT**
	MODERATE	Injury/illness requiring a maximum of first aid. No admission to health care facility. No lost time.	Damage to hardware. Damage repairable with minimal risk to project schedule or resources. Cost estimate <$10,000	**NEG**	**LOW**	**LOW**	**MOD**	**SIG**
	LOW	No injury/illness	Minimal damage to flight or project critical hardware.	**NEG**	**NEG**	**LOW**	**LOW**	**LOW**
	NEGLIGIBLE	No injury/illness	No damage to flight or project-critical hardware.	**NEG**	**NEG**	**NEG**	**NEG**	**NEG**

Table 1-2. Waiver Process

RISK RATING	HIGHEST LEVEL OF APPROVAL
Catastrophic (Outside Project System)	Laboratory Director of (Office)
Catastrophic (Within Project System)	Program or Project Manager
Significant	Project Office or System Manager
Moderate	Project Element Manager
Low	Systems Safety Office and Cognizant/Responsible Manager/Engineer for the highest level of assembly involved.
Negligible	

1.3.5 Verification

Activities performed to satisfy a safety requirement shall be documented. Acceptable documents include, but are not limited to:

(1) Procedures (QA verified).
(2) Inspection reports.
(3) Certified test reports (QA verified).
(4) Approved Analysis reports.

1.3.6 Discrepancy and Mishap Reporting.

Problems, failures, discrepancies, or other events that may have a potential impact on safety of personnel or hardware at JPL or JPL Contractors shall be recorded using existing reporting systems to the maximum extent practicable. The **SSO** shall be notified verbally or via email as soon as possible and shall receive a copy of the initial written report. The **SSO** shall also be on the concurrence signature list to permit systems safety assessment of the proposed close-out of the discrepancy (See Section 4.1.7 for personnel reporting responsibilities).

Significant items shall be submitted for consideration for inclusion in the JPL Significant Events File.

Examples of existing reporting systems at JPL and contractors include, but are not limited to :

IR	Inspection Report
P/FR	Problem Failure Report
NCR	Nonconformance Report
MRB	Material Review Board
TBD	JPL-approved Contractor Reporting Systems

1.3.6.1 *JPL Problem/Failure Reporting (P/FR*): JPL Document D-8091, "Flight and Support Equipment Problem/Failure Reporting and Analysis Requirements, JPL Standard (Level II)," defines the requirements for reporting, analysis, corrective action, review, and close-out of P/FRs for projects/tasks.

The **SSO** shall assure that all P/FRs are appropriately reviewed to determine if there is any potential adverse effect on personnel or hardware safety associated with the problem/failure. When significant comments exist, these shall be discussed with the cognizant engineer and conveyed to the P/FR Center within one working day. A safety rating of either "S" for a potential personnel or hardware safety concern, or "N" for no safety concern shall be assigned to each P/FR by the Cognizant Engineer or Technical Manager. It is the responsibility of each P/FR reviewer to determine that the assigned safety rating is appropriate. The safety rating of each P/FR shall be verified by the JPL Systems Safety Engineer or, when specified in the contract, by the Contractor Safety Engineer.

All P/FRs identified in the “S” category shall have a safety risk assessment and correction action included and shall be signed by the JPL Systems Safety Engineer, and if applicable, by the Contractor Safety Engineer.

For those payloads launched on the STS, all P/FRs shall be evaluated in terms of the potential effect of the failure on Shuttle personnel and/or hardware safety. The existence of any potential Shuttle hazard results in placing the P/FR in the "S" category for review and rating by the Safety Engineer. All P/FRs shall be reviewed by the Safety Engineer and assigned an STS criticality rating.

The term “system” refers to all flight and ground equipment including software procedures, and operating personnel comprising a particular project or task. (Ref. Para. 1.7.5)

P/FRs shall be rated “S” for either of the following:

(1) Any unplanned event that resulted in, or had the potential for, injury to personnel or for causing consequential damage external to the system.

(2) Any unplanned event which resulted in, or had the potential for, damage or stress to flight hardware or ground equipment internal to the system itself which is the result of failure to follow established procedures, processes or policies. “Common sense” shall be used

in applying “S” ratings to these P/FRs and can include some events that occurred even though established procedures and policies were followed.

P/FRs may be rated “S” for the following, dependant upon specified Project Policy:

(3) Any unplanned event which resulted in, or had significant potential for, hardware damage or stress, when all prescribed processes had been followed. (Items in this category include events such as: shorted cable wires/pins due to broken wire provided that initial safe-to-mate tests had been performed; procedure errors in appropriately reviewed and approved procedures which were not immediately obvious or intuitive to the qualified operator; ESD damage, provided that proper ESD controls were in use and practiced; inadvertent short to ground; test probes slipping during trouble shooting test; etc.)

1.3.6.2 *Mishap Reporting:* Any event or occurrence resulting in injury or property/equipment damage which meets the definition of a NASA mishap incident, or close call shall be reported as specified in JPL Safety Practice 4-08-22, “Reporting Mishaps.” Abbreviated definitions of reportable events are:

(1) Close Call. No injury or damage, but high potential for any of the events defined below.

(2) Type A Mishap. Death and/or damage of $1,000,000 or more.

(3) Type B Mishap. Disability to one or more persons, hospitalization of 5 or more persons, and /or damage between $250,000 and $999,000.

(4) Type C Mishap. Injury which results in lost workdays, and/or damage between $25,000 and $249,999.

(5) Incident. Personnel injury and/or damage between $1,000 and $24,999.

1.3.7 Reviews

1.3.7.1 *Project and Technical Review:* Safety shall be included on the agenda of all formal and informal reviews associated with a project at all levels (design, test readiness, preship, etc.). The safety material included shall be tailored to the nature of the review and the maturity of the project. In the case where there are no safety implications involved, a statement to that effect shall be included in the agenda next to the safety entry.

1.3.7.2 *Safety Surveys:* All operations or activities involving hazards and/or flight hardware or other JCI must be reviewed prior to initiating the operation or activity. Facility Safety Surveys (FSS) and Operations Safety Surveys (OSS) shall be conducted by the Systems Safety Office and designated team members to assure compliance with regulatory requirements for personnel and facility safety. Surveys for activities that involve no personnel hazards and are solely for the protection of flight hardware shall be in accordance with the approved Safety Plan for the specific project. (See Section 4.9 for implementation details and required attendance.)

Facility Safety Surveys (FSS) shall be performed to assure specific facilities are appropriate for the planned flight hardware activities.

Operations Safety Surveys (OSS) shall be performed to assure that the specific operation or activity to be conducted within a facility is safe for both personnel and flight hardware.

Transportation Safety Surveys (TSS) shall be performed for all significant movements of flight hardware, either on- or off-lab.

Note: At the discretion of the Cognizant Engineer, Operational Safety Reviews (OSR) conducted in accordance with the JPL Policy: Operational Safety Reviews may be substituted for an FSS and/or OSS for project operations or activities involving hazards to personnel or facility safety but <u>*not*</u> *involving flight hardware.*

1.4 PROCUREMENT

In accordance with JPL policy, contracts covering project or system activities shall include appropriate safety requirements. To implement this policy, a written Safety Plan to be approved by JPL shall be required for all contracts except those procuring “off-the-shelf” items. Data descriptions and submittal requirements for the Safety Plan as well as for any other required safety data shall be included in the RFP. Use of the JPL Data Requirement Description (DRD) form No. JPL 0768 and the Contract Data Requirements List (CDRL), JPL form No. JPL 1572 is recommended.

The specimen contract shall state the contractor's responsibilities and JPL's responsibilities and the order in which activities supporting those responsibilities shall take place. Information aiding a prospective contractor to understand the safety requirements for the task, safety program practices, organizational interface, and other topics shall be included in the Request for Proposal as appropriate to the particular procurement.

To reinforce the significance of the safety program, the organizational interface for safety matters shall be established at the highest possible level, preferably at the contractor program manager level.

This Document shall be used as a guideline for the evaluation of Contractor submitted Safety Plans, and may be tailored to the risk tolerance level of the project for the specific procurement. Different contracts within the same project may have differing risk tolerances; hence, the evaluation / tailoring may be different for each procurement. Tailoring may be performed for hardware protection requirements only.

1.5 CHANGES

This document shall be updated as required for sound technical, managerial, or policy reasons. Minor editorial changes shall be collected and incorporated with revisions for the more significant reasons.

1.5.1 Change Proposals

Change proposals for this document should be submitted to the Systems Safety Process Owner, Manager of the Systems Safety Office.

1.5.2 Evaluation of Change Proposals

The change proposals shall be evaluated by the Systems Safety Process Owner for the following:

(1) Need.

(2) Effect of the change on cost, schedule, manpower, and hardware.

(3) Scope of the proposed change (project unique or generic).

(4) Potential for conflict with external requirements.

1.5.3 Change Approvals

When satisfied that a change to this document is required, the **Systems Safety Process Owner** shall solicit the concurrence of the appropriate JPL management and implement the change.

1.5.4 Updates

This JPL Standard for Systems Safety document shall be maintained on the JPL DMIE Information System (DIS).

1.6 APPLICABLE AND REFERENCE DOCUMENTS

Applicable portions of the latest revisions of the following documents form a part of this requirements document. Additional documents are included for reference purposes and may be applicable, depending upon specific area safety requirements, such as the launch ranges. It is the responsibility of each Cognizant Engineer to become familiar with the applicable document requirements pertaining to his/her specific hazards. The **SSO** shall assist, advise, and inform the Cognizant Engineer to the maximum extent practicable. Any conflict between specific requirements and those contained in any of the documents below shall be resolved by the **SSO** at the lowest possible level. Final resolution will be brought to the attention of the Cognizant Engineer.

DOCUMENT NO.	TITLE
JPL DOCUMENTS	
4-08-41	Radio Frequency Transmitters
D-11634	Radiation Safety Program Plan
D-1348	Electrostatic Control For Assembly and Test Areas For Flight Projects
D-5814 (601-920)	Stress Corrosion Cracking Control Implementation
D6820 (601-930)	Structural Design and Verification Criteria
D-6904	Ground Handling Equipment Design Handbook
D-8091	JPL Standards Document, Problem/Failure Reporting System, Guidelines and Procedures
D-8208	Electronic Equipment and Cabling Design and Fabrication Requirements and Processing Techniques
ES 501492	Safety Requirements for Mechanical Support Equipment For JPL Critical Items, Detail Specification For
ES 511335	Nonflammable Material Requirements For Ground Support Electronic Equipment, Detail Specification For
FS 511316	Detail Specification for Qualification of Critical Fasteners
Policy	Electrical Safety

DOCUMENT NO.	TITLE
Policy	Lifting/Elevating Equipment Safety
Policy	Lockout/Tagout/Blockout
Policy	Policy: Operational Safety Reviews
Policy	Pressure Vessels and Systems
Policy	Safety Policy
Policy	Systems Safety Policy
SP 4-08-100	Safety Practice, JPL Critical Items
SP 4-08-22	Reporting Mishaps
SP 4-08-25	Lifting and Elevating Equipment
SP 4-08-31	Fire Protection for Essential Electronic Equipment
SP 4-08-41	JPL Critical Item On-Site Transport
SP 4-08-50	Radiation Safety Organization Duties and Responsibilities
SP 4-08-51	Radioactive Materials and Radiation Areas
SP 4-08-52	Radioactive Contamination
SP 4-08-53	Radioactive Materials/Radiation Machines – Acquisition and Transportation
SP 4-08-54	Design and Construction of Radiation Facilities
SP 4-08-55	Laser Hazards and Operations
SP 4-08-56	Ionizing Radiation: Operation of Radiation Producing Equipment

DOCUMENT NO.	TITLE
SP 4-08-57	Radiation Monitoring Instruments
SP 4-08-101	JPL Critical Item On-Site Transport
SPI 4-11-8	Selection of Fasteners for Flight Application
SPI 4-13-16	Airport Security Exemption Request
System Procedure:	Use of Non-Environmental Test Lab Facilities for Environmental Testing

JPL DRAWINGS

10001658	Nameplate - Assembly, Handling and Shipping Equipment.
10025963-1	Proof-test Label/AHSE

GOVERNMENT DOCUMENTS

(none)	Nuclear Safety Review and Approval Procedures For Minor Radioactive Sources in Space Operations. National Aeronautics and Space Council
10 CFR	Code of Federal Regulations: Title 10 Energy
21 CFR	Code of Federal Regulations: Title 21 Food and Drugs
29 CFR 1910	Code of Federal Regulations: Title 29 Occupational Safety and Health Standards
49 CFR	Code of Federal Regulations: Title 49 Transportation
AMC-R 385-100	Safety Manual, Dept. of Army
CCR: Title 17	California Code of Regulations: Title 17Public Health
CCR: Title 8	California Code of Regulations: Title 8 Occupational Safety and Health
DoD 4145.26	DoD Contractor's Safety Manual for Ammunition and Explosives

DOCUMENT NO.	TITLE
EWR 127-1[1]	Eastern /Western Range Safety Requirements
FED STD 209	Clean Room and Work Station Required Controlled Environment
JSC 11123	STS Payload Safety Guidelines Handbook
JSC 20793	Manned Space Vehicle Battery Handbook
KHB 1700.7	Space Transportation System Payload Ground Safety Handbook
MIL-HDBK-5	Metallic Materials and Elements For Aerospace Vehicle Structures
MIL-STD-1522	Standard General Requirements For Safe Design and Operation of Pressurized Missile and Space Systems
MIL-STD-1576	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems
MSFC-HDBK-527/ JSC 09604	Materials Selection List For Space Hardware Systems
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking
NASA STD-5001	Structural Design and Test Factors of Safety for Sapce Flight Hardware
NASA STD-5003	Fracture Control Requirements for Payloads using the Space Shuttle.
NEC	National Electric Code (NFPA-70)
NFPA 495	Code for Manufacture, Transportation, Storage, and Use of Explosive Materials
NFPA-493	Standard for Intrinsically Safe Process Control Equipment for use in Class 1 Hazardous Locations
NFPA-75	Fire Protection for Essential Electronic Equipment
NHB 8060.1	Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion
NPG 7120.5A	NASA Program and Project Management Processes and Requirements

DOCUMENT NO.	TITLE
NPG 8020.12	Planetary Protection Provisions for Robotic Extraterestrial Missions
NSTS 13830	Payload Safety Review and Data Submittal Requirements
NSTS 1700.7	Safety Policy and Requirements forPayloads Using the Space Transportation System; And Addendu – Safety Policy and Requirements for Payloads Using the International Space station
NSTS 07700	Shuttle Orbiter / Cargo Standard Interfaces
NSTS07770	Space Transportation System EVA Design Criteria
NSTS 18798	Payload Safety Panel Policies for STS Payloads
UL 913	Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, III, Division 1 Hazardous Locations

OTHER DOCUMENTS

BoE-6000-N	Hazardous Materials Regulations of the Department of Transportation, I.C.C. Tariff
JSC SP-R-0022	General Specification Vacuum Stability Requirement of Polymeric Material for Spacecraft Application
RS-CSG-ED(O)	CSG Safety Regulations (Guiana Space Center)

GUIDELINE DOCUMENTS

The following documents serve as guidelines:

MIL STD 882	System Safety Program For Systems and Associated Equipment
NASA-STD-8719.8	Expendable Launch Vehicle Payload Safety Review Process Standard
NHB 1700.1 (V I-B)	NASA Basic Safety Manual
NHB 1700.6	Guide for Inservice Inspection and Recertification of Ground-Based Pressure Vessels and Systems

DOCUMENT NO.	TITLE
NPD 8710.5	NASA Safety Policy for Pressure Vessels and Pressurized Systems
NSS/GO-1740.0	Safety Standard for Lifting Devices

1.7 DEFINITIONS

The following definitions are established to provide a common base of interpretation of requirements within this document. Due to the broad application of this document, it is recognized that the definitions in use on individual projects and by other institutions may vary in actual usage.

1.7.1 Project

See Paragraph 1.1.2.1.

1.7.2 Project Manager

See Paragraph 1.1.2.3.

1.7.3 JPL Critical Items

JPL Critical Items (JCI's) are project critical hardware, software, and test, or handling equipment, including fixtures or ground support equipment that if damaged or lost would:

(1) Jeopardize the success of the project, or;

(2) Increase the Project's cost substantially, or in any case have an impact of $100,000 or greater, or;

(3) Adversely affect the Project's schedule, or;

(4) Cause embarrassment to the Laboratory.

Included under this category are the following:

1.7.3.1 *Flight Hardware:* Flight hardware refers to any hardware/equipment that flies; that is, leaves the surface of the earth, on an aircraft, balloon, or rocket-launch vehicle. Equipment known as "Airborne Support Equipment" is included in this category.

1.7.3.2 *Flight-Critical Hardward:* Flight-critical hardware includes all flight hardware and project-critical hardware.

1.7.3.3 *Project-Critical Hardware:.* Project-critical hardware or equipment refers to those items which, if damaged or lost, would cause a major cost or schedule impact to the project (i.e., if the cognizant hardware organization would require significant additional funds or schedule time to meet the original commitment), or, if not replaced, would jeopardize the successful accomplishment of the mission or task. It may include any of the ground support equipment identified below and may also include mission support equipment and portions of Deep Space Network (DSN) ground stations which are critical to the mission or task. Functional replicas of flight equipment that are not intended for flight, such as engineering models, may also be designated Project-Critical if they provide a critical ground test capability, either before or after launch.

1.7.3.4 *Ground Support Equipment:* Ground Support Equipment (GSE) is defined as any equipment, electrical or mechanical, which is used to assemble, test, handle, or launch the flight equipment. It includes, but is not limited to, assembly and handling fixtures, system test complex and launch complex equipment, and transportation equipment. This may include equipment that does not directly interface to the flight equipment. Assembly, Handling, and Shipping Equipment (AHSE) is included under the broad definition of GSE.

1.7.4 Safety Critical

Safety critical refers to equipment, software, or functions which, if nonfunctional, inoperative, or incorrectly performed, could injure personnel or damage equipment.

1.7.4.1 *Hazard:* A hazard is a condition or changing set of circumstances that presents a potential for injury, illness, or property damage. It is the potential or inherent characteristics of an activity, condition, or circumstance which can produce adverse or harmful consequences.

1.7.4.2 *Hazardous Operation:* A hazardous operation is any process or series of functions in which one or more of the following conditions are present:

(1) Energy is involved and loss of control could result in injury to personnel or damage to equipment.

(2) A significant change from ambient condition shall occur; e.g. increase or decrease of pressure, temperature, or work-place oxygen content.

(3) Presence of hazardous materials which presents the potential for personnel exposure.

1.7.5 System

1.7.5.1 *Generic:* For the purposes of safety analyses and requirements implementation, system refers to all flight and ground equipment, including software, procedures, and operating personnel comprising a particular project or task.

1.7.5.2 *Hardware:* A system refers to the complete set of subsystems and equipment which shall perform the mission or project. It generally refers to a complete spacecraft or Shuttle experiment.

1.7.6 Subsystem

A subsystem refers to the first major division of a system, generally divided into functional elements. Examples could be: structure, power, propulsion, command, data, attitude control, telecommunications, etc. The functional divisions may vary from project to project.

1.7.7 Assembly

An assembly refers to the first major division of a subsystem.

1.7.8 Experiment

Refer to "project."

1.7.9 Task

Refer to "project."

1.7.10 *Environmental Test:* Environmental test refers to the intentional application of any environment which has the potential of damaging the hardware, regardless of the location of the test facility or the phase of the hardware cycle. This specifically includes environments imposed for processing, as well as those imposed for qualification or acceptance testing purposes.

1.7.11 Pressure Vessel

1.7.11.1 *Ground Based:* A container that stores fluids with a design pressure exceeding 103kPa (15 psi) and having an internal cross-sectional diameter, width, height, or diagonal greater than 15 cm (6 inches), with no limitation on length (JPL Safety Practice 4-08-70). This definition applies to ground based (non-flight) vessels pressurized in the presence of personnel.

Note: Even though devices specially fabricated from pipe, tubing, etc. technically may not be pressure vessels, they shall be reviewed by the JPL Safety Operations Section for acceptable design and fabrication.

1.7.11.2 Flight. For flight payloads, a container that stores pressurized fluids and:

(1) Contains stored energy of 19,310 Joules (14,240 ft. lbs) or greater based on adiabatic expansion of a perfect gas: or

(2) Contains a gas or liquid which will create a hazard if released: or

(3) Will experience a design limit pressure differential greater than 700 kPa (100 psi).

1.7.12 Maximum Operating Pressure

Maximum Operating Pressure (MOP) refers to the maximum pressure at which a pressure system or component actually operates in a particular application. The MOP may be at or below the Maximum Allowable Working Pressure. MOP is synonymous with MWP (Maximum Working Pressure) and MEOP (Maximum Expected Operating Pressure) and includes the effects of temperature, transient peaks, vehicle acceleration and relief valve tolerance.

1.7.13 Maximum Allowable Working Pressure

The Maximum Allowable Working Pressure (MAWP) is the maximum pressure at which a system or component may continuously operate based on allowable stress values and functional capabilities. MAWP is synonymous with MDP (Maximum Design Pressure), MDOP (Maximum Design Operating Pressure) and "Rated Pressure."

1.7.14 Ordnance

The term "electroexplosive ordnance" includes, but is not limited to, ignitors, initiators, explosives, pyrotechnics, and electroexplosive devices that are initiated electrically.

1.7.14.1 *Category A:* Ordnance devices which may cause injury or death to personnel or damage to facility property by the expenditure of their own energy, or by initiating a chain of events, shall be classified as Category A devices. Damage to project equipment only is not sufficient grounds for classifying a device as Category A.

1.7.14.2 *Category B:* Ordnance devices which are not classified as Category A shall be classified as Category B.

1.7.14.3 *Nonexplosive Initiators:* Nonexplosive initiators (NEIs) which are actuated by electrical impulse and whose function or actuation can result in a hazardous condition, and are designed to function one time, shall be treated as ordnance for circuit design purposes. This definition specifically excludes solenoid valves, relays, motors, etc.

1.7.15 Catastrophic Hazard

A hazard which can result in the potential for a disabling or fatal personnel injury, or loss of facilities or equipment.

1.7.16 Critical Hazard

A hazard which can result in damage to equipment, a nondisabling personnel injury, or the unscheduled use of safing procedures that affect operators of a JPL payload.

1.7.17 Structure

Parts and assemblies which sustain loads by providing physical support and/or containment.

1.7.17.1 *Allowable Strength Data:* Allowable strength data are those data obtained from the most recent revision of MIL-HDBK 5, "Metallic Materials and Elements for Aerospace Vehicle Structures" or from other sources approved by the Materials Engineer.

1.7.17.2 *Failure:* The condition under which the structure or any part thereof can no longer perform its intended structural function. Such a condition may be caused by instability, rupture, or excessive deformation.

1.7.17.3 *Limit Loads or Stresses*: Limit loads or stresses represent the maximum physical loads or stresses the structure is expected to experience under specified conditions of operation or use.

1.7.17.4 *Structure Classification*:

1.7.17.4.1 Primary Structure. Primary Structure is any structural element supporting more than 20 kg of mass.

1.7.17.4.2 Secondary Structure. Secondary structure is any structural element supporting less than 20 kg of mass.

1.7.17.5 *Ultimate Factor of Safety:* The ultimate factor of safety is a multiplying factor applied to a limit load or stress to obtain the load at which there shall be no structural failure.

1.7.17.6 Ultimate Load or Stress. The ultimate load or stress is the maximum load or stress a structure can sustain without failure.

1.7.17.7 Yield Factor of Safety. The yield factor of safety is a multiplying factor applied to the limit load to obtain the load at which there shall be no general yielding of the structure. This does not apply to local yielding at stress concentrations, etc.

1.7.17.8 Yield Load. Yield load is that load which produces yield at any location other than a stress concentration.

1.7.17.9 Yield Stress. Yield stress is the stress corresponding to 0.002 mm/mm strain offset of the stress strain curve of a material.

1.7.17.10 Rated Load. Rated load is the maximum load that may be applied at any given time.

SECTION 2

2 FLIGHT EQUIPMENT DESIGN REQUIREMENTS

This section of the JPL Standard for Systems Safety document applies to the design of all flight hardware/equipment.
Ground Support Equipment (GSE) and Test and Operations requirements are specified in Sections 3 and 4.

2.1 GENERAL

2.1.1 Fault Tolerance

Requirements for Fault Tolerance for the STS/ISS are contained in NSTS 1700.7 “Safety Policy and Requirements for Payloads Using the Space Transportation System.” Expendable Launch Vehicle Fault Tolerance Requirements can be found in EWR 127-1 “Eastern Western Range Safety Requirements.” As a general rule, Inadvertent operation leading to a catastrophic failure shall be inhibited by at least three independent mechanical or electrical inhibits (two-failure tolerant). Inadvertent operation leading to a critical failure shall be inhibited by at least two independent mechanical or electrical inhibits (one-failure tolerant).

2.1.2 Sharp Edge Criteria

2.1.2.1 *All Equipment:* Edges of flight equipment accessible to personnel shall be designed so as to preclude injury during handling and testing.

2.1.2.2 *Manrated (STS/ISS):* STS/ISS payloads are required by JPL policy to meet the sharp edge criteria specified in NSTS 26626A (EVA) hardware) and NSTS 21000-IDD-MDK Appendix 9 (IVA hardware)/SSP 52000-IDD-PRP (ISS) even when no intentional Extra Vehicular Activity (EVA) is planned.

2.2 ELECTROMECHANICAL DEVICES

For spacecraft which will be launched on an ELV, electromechanical devices (including NEIs) which are used for such purposes as structure deployment or actuation release mechanisms shall be evaluated to determine the possibility of damage to equipment or injury to personnel in the case of inadvertent activation. If damage or injury is determined to be possible, the device(s) shall be controlled in a manner similar to Category "A" ordnance devices. At least two independent serial actions shall be required prior to the activation of the device in flight and at least three independent serial actions for activation on the ground.

For payloads which will be launched on the STS/ISS, electromechanical devices which can fail catastrophically or cause catastrophic failure shall include a minimum of three independent electrical inhibits in the control circuit. Specific devices of concern include but are not limited to:

(1) Momentum wheels: overspeed.

(2) Linear or rotational actuators: actuation or movement which can damage or break support structures or hardware, or position the load so as to be structurally unsafe.

2.3 ELECTRICAL SYSTEMS

The following criteria govern safety design requirements for electrical power subsystems.

2.3.1 Batteries

Several types of batteries may be flown on spacecraft and each type has its own specific design and use requirements. Many of these contain compounds that are injurious to flight hardware and to personnel if released.

Batteries which will be flown on the STS/ISS should be designed and used following the guidelines identified in the "Manned Space Vehicle Battery Safety Handbook," JSC 20793. Pressurized Battery Cases shall meet the requirements of paragraph 2.7.1

2.3.1.1 *Terminals:* Batteries shall be designed so that terminals cannot be cross-connected and so that the wrong battery cannot be installed inadvertently.

2.3.1.2 *Wet-Cell Batteries:* Wet-cell batteries shall not be installed without adequate protection against battery leakage onto critical electrical, propellant, or pressure lines.

2.3.1.3 *High-Energy Density Batteries:* Batteries using lithium chemistry or other high-energy density materials pose a serious safety threat if not handled and installed properly. The following are design-related requirements:

(1) Design features of multiple cell batteries shall avoid the condition of, or control the hazards associated with, excessive discharge/cell reversal. These design features may include, but are not limited to:

(a) Preferred approach - Excess capacity. Design for operation within the first 70 percent (maximum depth of discharge) of total cell capacity.

(b) Alternate approach - Current shunting diodes. Provide each cell with a diode to shunt currents caused by reverse voltages past the cells.

(c) Alternate approach - Provide a low voltage cutoff device to remove the load whenever any single cell in the battery approaches zero voltage.

Additional safety-related design features for this type of battery are given in the NASA Goddard Space Center Handbook GHB 1710.5, "Lithium-Sulfur Dioxide Cell and Battery Safety," and in the Johnson Space Center Handbook JSC 20793 "Manned Space Vehicle Battery Safety Handbook". Appropriate features shall be incorporated into the battery design as required for specific battery applications.

2.3.2 Explosion-Proofing

The flight equipment shall be designed and constructed so that energizing or operating an electrical circuit during prelaunch, ascent, descent, or postlanding activities in the presence of flammable vapors cannot initiate an explosion or fire.

For STS/ISS launches, the payload shall be designed so that if launched powered, normal operation of the spacecraft shall not cause a hazard during entry, landing, (planned or abort) or postlanding activities. If launched unpowered, removal of power after turn on must be feasible within emergency de-orbit safety criteria timelines.

Special design consideration for explosion hazards shall be given to, but not be limited to, the following:

(1) Motors, mechanical contact switches, or other devices that may spark during use.

(2) Devices that incorporate items such as heated elements or open flame that develop temperatures high enough to ignite flammable vapors, dust, or other materials.

(3) Devices which employ arcs or spark discharges in their operation or incorporate voltages in excess of 100 volts which could conceivably cause corona or sparks.

(4) Items or materials which could react chemically with oxidizing materials (such as propellants), causing high temperatures or fires.

(5) Items which can produce flammable vapors or flammable dust.

(6) Oxidation-prone metals, such as magnesium, sodium, etc.

(7) Devices which normally operate in a pulsed mode which may overheat if continuously powered (such as isolation -latching valves, stepper motors, motorized switches, etc.).

2.3.3 Connectors

Connectors shall be selected and configured to satisfy the following safety-related requirements. (Ordnance connector requirements can be found in MIL-STD 1576.)

2.3.3.1 *Mismating:* All practicable efforts shall be made to ensure that any given electrical connector cannot be mismated or cross -connected to any other connector.

Positive mechanical methods such as connector type, size, keying, or pin configuration shall be used to prevent mismating or cross-connections of electrical connectors where improper assembly could result in a personnel hazard or equipment damage.

Where it is impracticable to use positive mechanical methods, the methods listed below may be used:

(1) Physical separation or l ocation.

(2) Cable length.

(3) Wiring bundle or harness configuration.

(4) Color coding.

(5) Accessory mechanical hardware.

Note: Use of these methods may require the submission of a waiver to the launch agency. Prior coordination with the SSO is required.

2.3.3.2 Parallel Power Pin Failure Use of these methods may require the submission of a waiver to the launch agency. Prior coordination with the SOS is required.

The failure open of one connector pin in a parallel power carrying configuration shall not generate hazardous temperatures in the remaining power carrying pin(s) at full-rated circuit load (see Section 2.3.2). The resulting voltage drop at the load shall not create a hazardous condition or cause a hazardous function to occur.

2.3.4 Lead Wires

The failure open of one lead wire in a parallel power carrying configuration shall not generate hazardous temperatures in the remaining power carrying wire(s) at full-rated circuit load. The resulting voltage drop at the load shall not create a hazardous condition or cause a hazardous function to occur.

2.4 ELECTROEXPLOSIVE SYSTEMS

The following requirements govern the basic design requirements for electroexplosive ordnance devices. Specific requirements for solid rocket motors are contained in Section 2.5.

Aspects of the devices and circuits which initiate catastrophic functions shall meet the requirements of NSTS 1700.7 and KHB 1700.7 if they will be flown aboard the STS/ISS.

Non-STS/ISS payloads shall meet the requirements stated in Eastern Western Regulations EWR 127-1 (see Section 4.11.2 for other launch areas).

The following requirements are extracted from the controlling documents and are included here for reference. For a complete set of requirements, use the appropriate document. Unless specified otherwise by an outside agency, the requirements of MIL-STD-1576 shall be met.

2.4.1 Classification

Electroexplosive ordnance devices shall be classified as either Category A or Category B. It is JPL policy, however, to design all circuitry, harness, and mechanical equipment in the same manner as Category A. Only the devices themselves are handled as Category A or Category B. This policy insures against mission degradation and possible spacecraft damage from inadvertent firing of Category B devices.

Note: Devices such as bellows actuators are treated as explosive devices and classified as Category A or B depending upon the function being controlled, but are classified as nonregulated material for shipping purposes by the Department of Transportation.

2.4.2 Safe and Arm Devices

2.4.2.1 *Installation*: A safe and arm device shall be installed to interrupt the explosive train between the igniting device and any ordinance devices such as solid propellant motors, destruct charges, liquid propellant motor start, etc. The igniting device shall be designed so that it can be installed in the equipment at the latest possible time in the final launch preparations.

2.4.2.2 *Use:* Safe and arm devices shall meet the requirements of MIL-STD-1576. This specification contains all the requirements for safe and arm devices including those for:

(1) Mechanical blocking.

(2) Electrical interrupt.

(3) Electrical short.

(4) Monitoring and control circuits.

(5) Safing.

(6) Safety pin.

(7) Arming.

2.4.3 Device Mechanical Design

2.4.3.1 *Impact and Friction Sensitivity:* The explosive material used in Category A devices shall have an impact sensitivity not greater than lead styphenate, and a friction sensitivity no greater than lead azide.

2.4.3.2 *Drop Tests:* Category A and B devices shall not detonate or ignite when dropped a distance of 1.83 meters (6 ft.) onto concrete in the most susceptible orientation.

2.4.3.3 *Shipping and Handling:* Devices shall withstand the vibration effects of shipping and handling without ignition or detonation, and shall function properly after subjection to vibration testing.

2.4.4 Device Electrical Design

2.4.4.1 *NASA Standard Initiator Requirement:* Electroexplosive devices which can initiate catastrophic functions shall meet the requirements of NSTS 1700.7 if they will be flown on the STS/ISS. The preferred method of meeting this requirement is to utilize the NASA Standard Initiator (NSI). Devices flown on expendable launch vehicles shall meet the requirements of MIL-STD-1576 as specified by EWR 127-1.

2.4.4.2 *Electrical Connector:* Electroexplosive devices shall contain an electrical connector, integral to the unit, so that the device can be connected and disconnected electrically from the firing circuits.

2.4.4.3 *No-Fire Current/Power:* The Category A device shall not initiate or deteriorate in performance when one ampere direct current and one watt power minimum are applied to the device for a minimum of five minutes.

2.4.4.4 Electrostatic Discharge Protection

2.4.4.4.1 Shielding Caps: Electroexplosive devices shall have shielding caps installed which meet the following requirements:

(1) The outer shells shall be made of conductive material.

(2) The outer shell shall make electrical contact with the device case.

(3) No gaps shall exist between the shielding cap and the case.

(4) The cap shall not contact the pins.

2.4.4.4.2 Bleed Resistors: Electroexplosive devices shall be protected from electrostatic hazards by the placement of resistances from line-to-line and from line-to-ground (structure) as appropriate. The placement of line-to-structure static bleed resistances is not considered to violate the single-point ground requirements as long as they are 10k ohms or more.

2.4.4.4.3 Electrostatic Discharge Test: All Category A devices shall be procured to MIL-STD-1576. Devices that are launched on the STS/ISS may be furnished by JSC.

2.4.5 Circuit Design For Category A Devices

MIL-STD-1576 shall be followed for the circuit design of all JPL electroexplosive systems (Category A or B). By JPL policy, Category B devices and firing circuits shall be treated as Category A devices in all aspects of circuit, harness, and hardware design (see Section 2.4.1). Specific requirements for cabling, shielding, firing, monitor and control circuits, electrical isolation, connector types, and pin assignments can be found in MIL-STD-1576.

2.4.6 Identification

Electroexplosive devices shall be color coded to indicate the explosive condition of the specific item. The color coding may be satisfied by the attachment of a permanent label of the appropriate color (as follows) with the simulator type, part number, and serial number listed:

(1)	Live explosive:	Natural
(2)	Inert-dummy model:	Yellow
(3)	Inert-resistance simulator:	Green*
(4)	Inert-bridgewire simulator:	Blue*

*Color coding of simulators is not required if the device is designed such that installation into the pyro device is not possible.

2.5 SOLID PROPELLANT MOTORS.

Solid propellants are chemicals so mixed that, once ignited, the mixture is rapidly converted from solid to gas at a predictable rate. Once a solid -propellant motor is ignited, it burns without oxygen from the air; thus, it is very difficult, if not impossible, to extinguish.

2.5.1 Design

Solid propellant motors can be explosive under certain conditions when mistreated; therefore, many safety features shall be designed into the motor.

2.5.1.1 *Propellant and Ignition Material Characteristics:* The propellant and ignition materials shall have a value as high as practicable for auto ignition temperature, and be as insensitive as practicable to impact, friction, and electrostatic discharge.

2.5.1.2 *Motor Case Design*

2.5.1.2.1 Safety Factors: As a minimum, the safety factors for motor case design shall use safety factors for non-manrated pressure vessels; however, high temperatures and stress due to structural loads shall be considered in addition to pressure stresses.

2.5.1.2.2 Conductivity: Solid motor cases shall be designed to prevent the accumulation of electrostatic charges on the case. The surface resistivity shall be demonstrated to be less than 1 x 108 ohms/sq.

2.5.1.3 *Ignitors*: Ignitors and the ignition system shall meet the requirements specified in Section 2.4.

The ignition system should be designed so that it can be separated from the motor and installed as late as possible in the motor or spacecraft assembly phase.

2.5.1.4 *Assembly to Spacecraft:* The motor and spacecraft shall be designed so that the motor can be placed into the spacecraft as late in the spacecraft assembly sequence as practicable.

2.5.1.5 *Motor Closures*: Nonelectrostatic-generating closures shall be provided for the solid-propellant motor nozzle and other case openings.

2.5.2 Inspection

Solid propellant motor performance can be significantly degraded by defects. Defects can also significantly increase the hazard level during handling and installation. The following inspections shall be performed to minimize potential accidents. A review of transportation, storage, and handling records shall be performed per Section 4.2.10.16.

2.5.2.1 *Visual Inspection*: Solid propellant motors shall be visually inspected for the following:

(1) Verification that safety features are in accordance with all directives.

(2) Condition of external motor safety devices, case, nozzles and igniter for dents, scratches, bent parts, or other visible damage.

2.5.2.2 *Nondestructive Inspection:* Solid propellant motors shall be subjected to appropriate nondestructive inspection techniques such as radiographic, ultrasonic, or microwave inspection to determine possible surface, internal or hidden flaws.

2.5.2.3 *Comparison of Inspection Records*: The results of the above inspections shall be compared with previous records to screen for changes or variations which may indicate potential problems.

2.6 LIQUID PROPELLANT SYSTEMS

The following safety requirements shall be applied to the design of liquid propellant systems.

2.6.1 Pressure Rating (Analytical Factors of Safety)

The pressure rating requirements for all flight tanks and components are defined in Table 2-1, Minimum Analytical Factors of Safety for Flight Hardware.

2.6.2 Temperature Limits (Valve Overheating)

Certain liquid propellants generate very high vapor pressures, rapidly decompose, or enter the autoignition range at elevated temperatures. Failed components can cause heaters or valve coils to be continuously energized and inadvertently create high temperatures in adjacent propellant tanks, lines, or components. High surface temperatures not fully contained within a sealed container may cause ignition of flammable vapors and are of specific concern during abort or reentry.

The following temperature limits shall be observed for all components of payloads:

Note: Worst-case temperatures of 71.1^oC (160^oF) or higher require compatibility data and verifications for use on STS/ISS.

2.6.2.1 *Anhydrous Hydrazine (N_2H_4):* The upper temperature limit for anhydrous hydrazine in a nonreactive container is 121.1 ^oC (250^oF).

2.6.2.2 *Monomethylhydrazine (MMH):* The upper temperature limit for monomethylhydrazine in a nonreactive container is 148.9 ^oC (300^oF).

2.6.2.3 *Nitrogen Tetroxide (N_2O_4):* The upper temperature limit for nitrogen tetroxide is 148.9^oC (300^oF). At this temperature, the vapor pressure is in excess of 6.85 MPa (1000 psig).

2.6.2.4 *Materials Compatibility:* Materials that are exposed to MMH, N_2H_4, or N_2O_4 shall be compatible with these propellants at the worst-case expected temperature or at 71.1^oC (160^oF), whichever is higher. The worst-case expected temperature is the maximum temperature reached after two failures.

If the worst-case expected temperature could exceed 93.3 °C (200 °F), the materials testing to verify compatibility should be conducted at a temperature 10 °C (50 °F) above the worst-case temperature in order to provide a margin of safety.

A worst-case expected temperature above 148.9 °C (300 °F) is not acceptable and shall be prevented.

2.6.3 Propellant Isolation

For propellant systems which will be launched or recovered using the STS/ISS, each propellant delivery system shall have at least three independent propellant flow control devices in series. For bipropellant systems, these devices shall prevent mixing of the fuel and oxidizer, as well as prevent expulsion through the thrust chamber (refer to NSTS 1700.7).

Propellant systems launched on ELV's shall have a minimum of two independent flow control devices in series (refer to EWR 127-1).

2.6.3.1 *Pyro Valves:* Normally closed pyro-operated valves which have a solid-billet isolation without welds between the valve inlet and outlet can be considered to satisfy two of the independent devices, provided that the pyro firing circuit has the required inhibits.

2.6.3.2 *Solenoid Valves:* Dual poppet/seat (series) solenoid valves can be considered as two independent inhibits provided that the poppets are not mechanically connected and that the solenoid valve control circuit has the required inhibits.

2.6.3.3 *Power Off Isolation:* At least one of the propellant flow control devices shall return to the closed position upon removal of all power.

2.6.4 Adiabatic Compression

The potential for propellant ignition due to adiabatic compression during opening of any of the propellant flow control devices shall be prevented. For launch vehicle payloads, the potential shall be considered in the propulsion system and sequence design.

2.6.5 Materials

Materials selected for use in propellant systems shall be compatible with the propellants as well as any referee or cleaning fluids which might come in contact with the system during its fabrication, test and assembly operations. The Space Materials Science and Applications section shall be consulted on all materials applications.

2.6.6 Drain Provisions

Propellant systems shall incorporate low point drain ports with service valves to allow removal of propellants when the flight system is in the launch attitude. Liquid and gas service valves shall be positioned so as to allow access in order that contingency off-loading and de-pressurization may be performed when necessary.

2.7 PRESSURIZED SYSTEMS

2.7.1 Pressure Vessels

All pressure vessels used at or by JPL shall have a fracture mechanics analysis performed (see Section 3.9.1 for nonflight pressure vessels). Stress corrosion cracking control shall be implemented as specified in JPL document D-5814.

2.7.1.1 *Authority:* JPL requires that all pressure vessels be designed by the use of fracture mechanics criteria in accordance with NASA STD-5003 . The application of this technique fulfills the requirements of MIL-STD-1522, NHB8071.1, and NSTS 1700.7.

Note: Liners of Composite Overwrap Pressure Vessels (COPV) which operate above yield do not have to exhibit a positive margin of safety.

2.7.1.2 *Design Approval*: Pressure vessel designs shall be approved by the Structures and Materials Review Committee (SAM-RC) prior to fabrication. Any deviation from the established requirements shall be approved by the SAM -RC and by the **System Safety Office.**

2.7.1.3 *Materials:* Materials to be used in the fabrication of pressure vessels shall have metallurgical, physical, and mechanical properties consistent with those used in their analysis.

2.7.1.4 *Materials Compatibility:* The materials used in the fabrication of a pressure vessel shall be compatible with the total internal and external environment. Specific attention shall be devoted to potential embrittlement, (i.e.: Hydrogen, etc.) stress corrosion, and general corrosion mechanisms of the vessel materials.

2.7.1.5 *Stress Concentrations:* Stress concentration on pressure vessels and other associated components shall be minimized, and shall be considered in the fracture mechanics and stress analyses.

2.7.1.6 *Minimum Factors of Safety:* The minimum Factors of Safety for Pressurized Flight Hardware are specified in Table 2-1.

Table 2-1. Minimum Analytical Factors of Safety for Pressurized Flight Hardware

Item	NSTS	ELV
	Ultimate (b)	Ultimate (b)
Reference Documents	NSTS 1700.7	EWR 127-1[1]
Pressure Vessels Metallic Vessels Composite Vessels	 1.5 (e) 1.5 (e)	 1.5 (d) 1.5 (d)
Components Tubing, piping, fittings, hoses, Connections Diameter less than 3.8 cm (1.5 inches) Diameter equal to 3.8 cm (1.5 inches) or greater	 4.0 1.5	 4.0 2.5
Filters, valves, transducers, actuating Cylinders, etc.	4.0	2.5
Actuating cylinders not pressurized in the presence of personnel	2.5	2.5
Transportation Interfacility transport of NSTS – Launched pressure vessels at KSC	 2.0	 -
Interfacility Transport of ELV-launched Pressure vessels Metallic vessels Hazardous LBB or BBL Composite Vessels Nonhazardous LBB Hazardous LBB or BBL	- - - -	- 1.5 1.5 (c)(e) 1.5 (c)(e)

(a) Allowable factor on Maximum Operating Pressure (MOP) or maximum stress level.
(b) Yield stress shall be greater than limit stress and also greater than proof test levels specified in Table 2-2.
(c) Transportation environments shall be considered in pressure vessel design. SSO shall be contacted for the latest requirements.
(d) For vessels less sensitive to creep rupture than S glass, life at stress of less than 1 year or flaws limited to less than 0.1of the thickness, consult the SSO for required safety factors.
(e) Fracture mechanics requirements are the same as for the metallic vessels, but apply to the metallic liner only

2.7.1.7 *Proof-Tests*: Each tank shall be proof-tested to a level equal to the maximum pressure the pressure vessel will experience in operation at any given temperature times a proof factor (PF) scaled by the ratio of the pressure vessel material ultimate strength at the proof-test temperature to the strength at the operating temperature. The PF depends on the contents of the pressure vessel (hazardous or not), the mode of failure (brittle or ductile), and the ratio of yield strength to ultimate strength (Fy/Fu) of the pressure vessel material at operating temperature as shown in Table 2-2.

2.7.1.8 *Cleaning and Referee Fluids*: Pressures within pressure vessels wetted with cleaning fluids or referee fluids (freon or isopropyl alcohol, etc.) shall be limited to a maximum of 25 percent of the maximum allowable working pressure.

2.7.1.9 *Life History Plan:* Each pressure vessel shall have fracture mechanics evaluation of the particular materials, fluids and environments to which the vessel will be exposed, both internally and externally, during its entire life history. The life history plan for each vessel shall be documented and available for comparison with the documented test history log in the pressure vessel log book. Fracture mechanics data must be available for all fluids used on or inside a pressure vessel as well as the vessel material itself.

2.7.1.10 *Life History Log:* A pressure vessel log book shall be maintained to document the actual pressure level, fluid, environment and test history of each pressure vessel.

Table 2-2. Flight Hardware Minimum Test Factors

Items	Ultimate Factor (a) Ref. Table 2-1		Proof-test Factor (b)	
	Metal Vessels 1.5 =2.0	Composite Vessels 1.5 =2.0	Metal Vessels 1.25 1.5	Composite Vessels 1.25 1.5
3.1) Pressurized components (other than rigid pressure vessels) including filters, valves, transducers, and pressurized actuating cylinders	2.5		1.5	
3.2) Line segments, hoses, and findings	4.0		1.5	
4) Complete pressure system with tanks without tanks			1.25(c) 1.50(c)	
5) Actuating cylinders not pressurized in presence of personnel	2.0		1.50	
6) Safety/Mission critical springs	N/A		1.25(d)	

Notes:

Other tests may be used in lieu of, or in addition to, those above, such as manufacturing operations (room sizing) or inspection (cryogenic temperature proof).

(a) Shall be demonstrated by test for one item of each type. This demonstration may be by similarity.

(b) Shall be demonstrated by test for every item.

(c) Reference Para. 2.7.2.2

(d) For compression springs that do not have sufficient travel for this proof-load, the spring shall be compressed to its solid length.

2.7.2 Lines, Fittings, and Components

2.7.2.1 *Minimum Safety Factors:* Pressure components (tubing, components, and fittings) shall be designed for the minimum Factors of Safety shown in Table 2-1.

2.7.2.2 *Proof-Test Factors:* Complete flight pressure systems with tanks installed shall be proof-tested as a system to the factors shown in Table 2-2.

As an alternate in all welded systems where the maximum allowable pressure vessel proof test level is lower than that of the remainder of the system, the system shall be proof tested to the higher level prior to making the final pressure vessel to system closure weld. After this weld is completed, the pressure vessel and closure weld shall be proof tested to the maximum allowable pressure vessel proof test level. Special qualification and/or inspection requirements may be required on unproofed welds.

2.7.3 Pressure Relief Devices

Pressure relief devices for flight systems shall be sized to limit the tank or system pressure to a maximum of 110 percent of the maximum allowable working pressure at the maximum possible input flow rate. Special consideration shall be given to the pressure generation rates for reactive fluids. The vents shall be designed and positioned in such a way to not cause an additional safety hazard to personnel.

2.8 CRYOGENIC SYSTEMS

2.8.1 Flight System Requirements

Systems utilizing cryogenics and carried aboard the STS/ISS shall meet the requirements of documents NSTS 1700.7 and KHB 1700.7. Systems launched by expendable launch vehicles shall comply with EWR 127-1.

2.8.2 Relief Devices

Pressure relief devices shall be included in all flight cryogenic system designs. Special consideration shall be given to the required flow rates for cryogenic designs, particularly for super fluid cryogens due to the rapid gassification phenomena.

The relief pressure performance shall be verified at the cryogenic temperature at which the device is expected to operate.

2.9 STRUCTURE

Structural safety for spacecraft is governed by the requirements given below and the following JPL documents:

NASA STD-5003	Fracture Control Requirements for Payloads using the Space Shuttle
JPL D-5814 (601-920)	Stress Corrosion Cracking Control Implementation Plan
NASA STD-5001	Structural Design and Test Factors of Safety for Space Flight Hardware

Application of these documents is mandatory for all hardware of payload systems launched on the STS/ISS. At the discretion of the Project Manager, any or all of these plans may be applied to the systems launched by Expendable Launch Vehicles.

2.9.1 Structure Requirements

Primary structure shall be designed using materials with MIL-HDBK -5 "A" values (99% probability and 95% confidence).

2.9.1.1 *Ultimate Factor of Safety*: Minimum analytical factors of safety for flight hardware structure are as specified in NASA STD-5001.

2.9.1.2 *Additional Factors:* Additional factors shall be applied to the yield and ultimate factors of safety if analysis uncertainties exist in areas such as joints and fittings, etc.

2.9.1.3 *Yield Margin of Safety:* The yield margin of safety shall be calculated as follows:

$$MS_{(yield)} = \frac{\text{yield load or yield stress}}{\text{(limit load or stress)} \times FS_{(yield)}} - 1$$

Where $FS_{(yield)}$ is the yield factor of safety multiplied by any additional factors. The yield margin of safety shall always be positive.

2.9.1.4 Ultimate Margin of Safety: The ultimate margin of safety is defined as follows:

$$MS_{(ult)} = \frac{\text{ultimate load or stress}}{\text{(limit load or stress)} \times FS_{(ult)}} - 1$$

Where $FS_{(ult)}$ is the ultimate factor of safety multiplied by any additional factors. The ultimate margin of safety shall always be positive.

2.9.1.5 *Fracture-Critical:* Composite/Bonded Structures (STS/ISS). Composite/bonded structures which are intended for flight on the STS/ISS and which are deemed fracture-critical shall be shown to meet fracture control requirements (NASA STD-5003) by one of the following methods:

(1) Design composite/bonded components for fracture-critical applications in such a way that the maximum strain level at limit

load is less than the material's damage-tolerance threshold strain level. The threshold strain level shall be determined by testing preflawed coupons or, with prior approval of the SAM-RC, by using available data.

(2) Test-verify that the fracture-critical composite/bonded component has a safe life of at least four lifetimes. This safe-life test shall be conducted on a full-scale flight-like article with controlled flaws. The location of the controlled flaws shall be determined by thorough stress analyses or tests and their size and shape shall correspond to the detection capability of the NDE to be imposed on the flight part. Prior to the performance of a safe-life test program, a comprehensive test plan shall be prepared and submitted to the SAM-RC for approval.

For all fracture-critical composite/bonded components, only manufacturing processes and control that are demonstrated to be reliable and consistent with established aerospace industry practices shall be used. Procedures for the prevention of damage resulting from handling, testing, or final assembly shall be implemented and approved by the SAM-RC.

All fracture-critical composite/bonded components shall be proof tested to at least 120 percent of the limit load. The proof test shall be conducted on the flight articles and may be accomplished at the component, assembly, or system level. When it is impractical or impossible to perform this test, a waiver(s) with appropriate rationale will be considered by the SSO for submittal to the STS/ISS Safety Review Panel on a case by case basis (Refer to Section. 1.3.4).

2.9.2 Ground Handling Attach Points.

2.9.2.1 *Flight Interfaces:* Lifting and handling loads and load paths for equipment attaching to flight interface points shall be included in the analyses on the flight structures.

2.9.2.2 *Special Attachment* Provisions*:* Special GSE lifting and handling attachment provisions designed into the flight hardware shall be analyzed and/or tested to verify that the attachment points and load paths have the same margin of safety for ground handling as is required for the flight load paths.

2.9.3 Fasteners

Fasteners to be used in flight applications shall be chosen in accordance with Standard Practice Instruction 4-11-8, "Selection of Fasteners for Flight Applications". Fasteners which are designated "Fracture Critical" or "Shear Critical" shall be qualified in accordance with JPL FS 511316 "Detail Specification for Qualification of Critical Fasteners".

2.9.4 Safety Critical Springs

Structural requirements for safety critical springs will be d etermined on a case by case basis by the structures group of the Science and Technology Development Section.

2.10 MATERIALS

2.10.1 Certification (STS/ISS)

All STS/ISS payload hardware shall be reviewed by the JPL Materials Engineering Group to verify compliance with the material safety requirements of JSC SP-R-0022, "General Specification, Vacuum Stability Requirements of Polymeric Material for Spacecraft Application and the outgassing requirements of NSTS 07700, Volume XIV. The requirements contained in Section 2.10 constitute the applicable NSTS requirements. A representative of the Materials Engineering Group shall certify that the requirements are satisfied and this certification shall be included in the appropriate hazard report(s). The certification documentation shall contain the following information:

(1) Specific identification of the hardware reviewed including the component top assembly part numbers.

(2) A summary of the materials and processes items reviewed, i.e., stress corrosion, flammability, toxicity, fluid system compatibility, thermal vacuum stability, etc.

(3) Reference to any Materials Usage Agreements (MUA) applicable to the hardware and their disposition status.

(4) Statement of flight acceptability.

All supporting data used to certify the material usage shall be kept on file until one year past launch of the subject payload or one year after payload retrieval.

2.10.2 Structures and Materials Safety Review Committee (STS/ISS & Non-STS/ISS)

The JPL Structures and Materials Safety Review Committee (SAM-RC) shall review all materials used for STS/ISS payload flight hardware to verify compliance with material safety requirements. The SAM-RC review shall specifically include a verification of the following material safety requirements:

- Stress Corrosion Cracking (Section 2.10.5)
- Flammability (Section 2.10.7)
- Hazardous Fluid Compatibility (Section 2.10.8)
- Offgassing (Section 2.10.9)
- Hazardous Chemical Releases (Section 2.10.10)

For Non-STS/ISS payloads, the SAM-RC review and its scope shall be at the discretion of the project manager. As a minimum, a peer review of the safety aspects, materials and structural design shall be performed.

2.10.3 Materials and Processes Control Plan

A Materials and Processes Control Plan shall be prepared that includes all of the safety and outgassing requirements contained in Section 2.10. The Plan shall also specify all criteria, procedures, and controls necessary to satisfy these requirements.

2.10.4 Materials and Processes Control

A JPL Materials and Processes Specialist shall sign-off on all JPL Drawings. In cases where JPL is not the design agency (eg. system/subsystem contracts) all materials used on flight hardware shall be documented in a Material Identification and Usage List (JPL Forms 2449, 2450, 2451, and 2452). Completed forms shall be submitted to the JPL Materials Engineering Group for approval.

2.10.5 Stress Corrosion Cracking Control

2.10.5.1 *Stress Corrosion Cracking Control (STS/ISS):* The selection of metallic materials shall comply with the requirements of JPL D-5814 (601-920), "Stress Corrosion Cracking Control Implementation Plan." All fracture-critical, fail-safe, or safety-critical components, including payload structure, support bracketry, and mounting hardware, shall be made of materials highly resistant to stress corrosion cracking, i.e., Table I materials per MSFC-SPEC-522, "Design Criteria for Controlling Stress Corrosion Cracking," or "A" rated materials per MSFC-HDBK-527/JSC-09604. Non-Table I or non-"A" rated materials proposed for use in fracture-critical, fail-safe, or safety-critical hardware shall pass a screening assessment based on sustained tensile stress. A Material Usage Agreement (JPL Form 2453) and Stress Corrosion Evaluation Form (JPL Form 2448) shall be completed documenting this assessment for fracture-critical or safety-critical hardware. An MUA and Stress Corrosion Evaluation Form shall be completed for fail-safe structure per the criteria in NASA STD-5001. Completed MUA's shall be submitted to the JPL Materials Engineering Group for approval and shall be referenced in the Stress Corrosion Hazard Report.

Non-Table I, non-"A" rated materials proposed for use on non-fracture-/safety-critical hardware shall have rationale to support the nonhazard condition. This rationale shall be documented in a Material Identification and Usage. Agreement and a stress corrosion evaluation form.

2.10.5.2 *Stress Corrosion Cracking (SCC) Control (Non-STS/ISS):* For non-STS/ISS applications, all fracture critical structure hardware shall be fabricated using alloys listed in Table 1 of MSFC-SPEC-522, "Design Criteria for Controlling Stress Corrosion Cracking," or "A" rated materials per MSFC-HDBK-527/JSC-09604. Pressure vessels and rotating machinery with greater than or equal to 19,310 Joules (14, 240 ft.

lb.)of kinetic energy shall always be considered as fracture critical. Non-Table I or non-"A" rated materials proposed for use in fracture-critical hardware shall pass a screening assessment based on sustained tensile stress. A Material Usage Agreement (JPL Form 2453) and Stress Corrosion Evaluation Form (JPL Form 2448) shall be completed documenting this assessment. The completed MUA and Stress Corrosion Evaluation Form shall be submitted to the JPL Materials Engineering Group for approval and shall be referenced in the stress corrosion hazard report.

All non-fracture critical hardware shall be fabricated using alloys listed in Table 1 or 2 of MSFC-SPEC-522, "Design Criteria for Controlling Stress Corrosion Cracking," or "A" or "B" rated materials per MSFC-HDBK-527/JSC-09604. Table III or "C" rated materials shall be considered for use only in applications where the probability of SCC is remote. If Table III or "C" rated materials are proposed for use, a Material Usage Agreement (JPL Form 2453) and Stress Corrosion Evaluation Form (JPL Form 2448) shall be completed documenting the rationale for use.

2.10.6 Outgassing

2.10.6.1 *Outgassing (STS/ISS):*

All organic materials shall meet the requirements of JSC SP-R-0022, "General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application." The basic requirement is that organic materials used in vacuum applications exhibit a total mass loss of less than 1% and a collected volatile condensable material of less than 0.1% when tested in accordance with SP-R-0022, ASTM-E-595, or JPL TS 507035. An approved Material Usage Agreement (JPL Form 2453) shall be used to document organic materials usage in excess of 10 grams (0.35 ounces), which cannot be rationalized per JSC SP-R-0022.

Note: This a general agreement. Contamination sensitive surfaces, such as optics or thermal control surfaces, may have more stringent requirements as specified by the Project Documentation.

Off-the-shelf items (black boxes) that incorporate materials not specifically identified on a materials list or drawing and items whose identification becomes impractical should be thermal vacuum baked. The baking should be done at a pressure of less than 1.33 mPa (10^{-5} Torr) at the highest allowable temperature for a sufficient period of time to reduce the rate of outgassing to a level where the outgassed products cannot contaminate sensors, electronics, optical surfaces, etc.

2.10.6.2 *Outgassing (Non-STS/ISS):* The < 1% Total Mass Loss (TML) and <0.1% Vacuum Condensable Materials Requirements of JSC-SP-R-0022 are applicable to non-STS/ISS Payloads. For ELV which require less outgassing, the project office shall establish the level of control to be used to control outgassing. This determination will be made based on the flight hardware, the intended mission and the risk to the project if no controls are imposed.

2.10.7 Flammability

2.10.7.1 *Flammability (STS/ISS):* All materials shall meet the flammability requirements of NSTS 1700.7. When flammable materials are used in quantities greater than those specified in NSTS 1700.7, the method of control of flame propagation shall be documented in an approved Materials Usage Agreement (JPL Form 2453).

Materials flammability shall be tested in accordance with NHB 8060.1 Test 1, "Upward Flame Propagation," NHB 8060.1 Test 8, "Flammability Test for Materials in Vented and Sealed Containers," or by configuration tests that establish whether a material can ignite and propagate fire in its use configuration.

Electrical wire insulation shall be tested for f lammability in accordance with NHB 8060.1 Test 4, "Electrical Wire Insulation Flammability," and for arc tracking in accordance with NHB 8060.1 Test 18, "Arc Tracking."

2.10.7.2 *Flammability (Non-STS/ISS):* All materials shall be evaluated for flammability characteristics. Material flammability shall be determined in accordance with NHB 8060.1 Test 1 and other applicable tests. A system flammability evaluation, per the guidelines of NHB 8060.1, shall be conducted if flammable materials are proposed for use. The rationale for use of flammable materials or multiple applications of flammable materials, that are proposed for use in amounts greater than 0.45 kg (1 pound) or 30.5 cm (12 inches), shall be documented in a Materials Usage Agreement (JPL Form 2453) and submitted for approval.

Electrical wire insulation shall be tested for arc tracking in accordance with NHB 8060.1 Test 18, "Arc Tracking." Wire insulation materials that are proposed which do not meet the criteria of NHB 8060.1 Test 18 shall be documented in a Materials Usage Agreement (JPL Form 2453) and submitted for approval. NOTE: that the addition of some organic pigments will make Teflon wire insulation burn in environments where it would normally be nonflammable. Note also that wire insulation made from polyamide polymers has been shown to pyrolyze furiously once initiated by electric arcing. The process will continue until the material is completely pyrolyzed, or until the voltage source is interrupted. The current in the arcing condition can be insufficient to blow circuit protection fuses, if present. The potential for, and the consequences of, this condition shall be assessed in the review of cabling, circuit, and circuit-board designs.

2.10.8 Hazardous Fluid Compatibility

2.10.8.1 *Hazardous Fluid Compatibility (STS/ISS):* All materials shall meet the fluid systems compatibility requirements of NSTS 1700.7. Materials compatibility with liquid and gaseous oxygen shall be evaluated in accordance with NHB 8060.1 Test 13, "Mechanical Impact for Materials in Ambient Pressure LOX (Test 13A)" and "Mechanical Impact for Materials in Variable Pressure LOX and GOX (Test 13B)," and Test 17, "Upward Flammability of Materials in GOX." When a material in an oxygen system fails the criteria of either test at its maximum use pressure, the system safety rationale shall be documented in an approved Material Usage Agreement (JPL Form 2453).

Materials compatibility with hazardous fluids other than oxygen shall be tested for 48 hours at the maximum system temperature or 71.1°C (160°F) (whichever is the higher) in accordance with NHB 8060.1 Test 15, "Compatibility of Material with Type "J" Fluids," or NHB 8060.1 Test 15, "Reactivity of Materials in Aerospace Fluids." Existing data showing compatibility may be used if approved by the JPL Materials Engineering Group. Materials shall be considered to be compatible with the test fluid if exposure results in no deleterious changes in the material and no visible change in color of the test fluid.

When materials can be exposed to hazardous fluids by a credible single barrier failure, an engineering evaluation and analysis of test data shall be conducted to demonstrate the acceptability of the configuration.

2.10.8.2 *Hazardous Fluid Compatibility (Non-STS/ISS*): All materials that are exposed to hazardous fluids shall be evaluated for compatibility with the fluid in their application. A hazardous fluid is any fluid that could chemically or physically degrade the system or cause an exothermic reaction. All materials that are exposed to the fluid shall be rated compatible per MSFC-HDBK-527/JSC-09604. Existing data showing compatibility may be used if approved by the JPL Materials Engineering Group. If a material is proposed for use that fails the compatibility requirements, the system safety rationale shall be documented in an approved Material Usage Agreement (JPL Form 2453).

When materials can be exposed to hazardous fluids by a credible single barrier failure, an engineering evaluation and analysis of test data shall be conducted to demonstrate the acceptability of the configuration.

2.10.9 Materials Offgassing in Habitable Areas (STS/ISS)

All materials used in habitable flight compartments shall meet the offgassing requirements of NHB 8060.1 using the following methodology.

2.10.9.1 *Offgassing Tested as Assembled Article:* Summation of Toxic Hazard Index (T) values of all offgassed constituent products (total concentration in milligrams per cubic meter/Spacecraft Maximum Allowable Concentration) shall not exceed 0.5.

2.10.9.2 Hardware Components Evaluated on a Materials Basis (individual materials used to make up components): The summation of T values for each constituent material shall be less then 0.5.

2.10.9.3 *More Than One Hardware Component or Assembly:* If a single hardware component is tested or evaluated for toxicity, but more than one will be flown, the T value obtained for one unit times the number of flight units shall be less than 0.5.

2.10.9.4 Bulk Materials and Other Materials Not Inside a Container : All materials shall be evaluated individually using the ratings in MSFC-HDBK-527/JSC 09604. The maximum quantity and associated rating is specified for each material code. The JPL Materials Engineering Group shall track the amount of each material being used to ensure the maximum quantity shall not be exceeded.

2.10.10 Hazardous Chemical Containment

2.10.10.1 *Hazardous Chemical Containment (STS/ISS):* The use of chemicals (such as mercury) which would create a toxicity problem or cause a hazard to STS/ISS hardware if released, shall meet the containment requirements of NSTS 1700.7. All such chemicals and containment methods shall be documented in an approved JPL Materials Usage Agreement (JPL Form 2453).

2.10.10.2 *Hazardous Chemical Containment (Non-STS/ISS):*) The use of chemicals (such as mercury) which would create a toxicity problem or cause a hazard to flight hardware if released shall be adequately contained. All such chemicals and containment methods shall be documented in an approved JPL Materials Usage Agreement (JPL Form 2453).

2.11 COMPUTER SYSTEMS AND SOFTWARE

This section provides safety guidelines for the design and development of all systems, flight and ground, in which computing systems have or potentially have safety critical applications. Unless specifically excluded and approved by Systems Safety, all safety critical computing systems associated with the handling, checkout, test, or launch of spacecraft shall be designed in accordance with safety identified in the project safety plan. These requirements include safety critical computing systems used in pre-launch assembly operations such as software controlled cranes.

The NASA Software Safety Standard NSS 1740.13, provides requirements for implementing software safety as an integral part of the overall system safety program. It describes the activities necessary to ensure safety is designed into software and maintained throughout the software cycle. NSS 1740.13 can be used as a guideline for establishing an appropriate software safety program for a project with safety critical software applications.

2.11.1 Determination of Software Safety Critical Functions (SSCF)

a. Software used to control or monitor the functioning of safety critical hardware shall be considered a software safety critical function (SSCF).

b. Software used to or having the capability to monitor or control hazardous systems shall be considered an SSCF.

c. Software associated with fault detection of safety critical hardware and/or software shall be considered an SSCF. NOTE: Fault is defined as the manifestation of an error in software. The term fault detection includes software associated with fault signal transmission.

d. Software responding to the detection of a safety critical fault shall be considered an SSCF.

e. Processor interrupt software associated with previously designated SSCF shall be considered an SSCF.

f. Computation of safety critical data used in a previously designated SSCF shall be considered an SSCF.

Note: It Is recommended that SSCFs are identified and agreed to with Systems Safety early in the program. Boundaries defining what is included and excluded from each SSCF should be documented.

2.11.2 Fault Tolerance

For the purposes of determining the fault tolerance of a system, a computer system (hardware/software combined) shall be considered as zero fault tolerant unless different computers (hardware and type) using independently developed software are used to control different inhibits to a hazardous function (see Section 2.1.1).

2.11.3 Software Hazard Analysis (SHA)

A software hazard analysis (SHA) shall b e performed on software containing safety-critical functions. The effects of command input timing and of processor timing shall be included in the analysis.

Waivers of software safety requirements shall meet all the procedures and criteria for hardware safety requirement waivers (see section 1.3.4).

2.11.4 Hardware/Software Inhibits

Wherever practical, safety-critical functions shall include at least one noncomputer-controlled inhibit which will preclude the inadvertent occurrence of hazardous functions in the event of a computer hardware or software failure. The total number of required inhibits shall meet the safety fault-tolerance requirements of the spacecraft and/or the launch vehicle system.

2.11.5 Software Safety Requirements

Based upon the information derived from the SHA a set of applicable safety requirements shall be established. Some software safety requirements will be established in response to system specific hazards, such as initiation of pyrotechnics, engine firings, deployment of appendages, etc. Other requirements are more "generic" in that their primary focus is to improve the reliability that hazards will be inadvertently introduced into the software. Typical "generic" software safety requirements include:

- Modularization to minimize and isolate interaction between safety critical and non-safety critical software
- Use of coding standards
- "The system shall power up in a safe state."
- "Modules shall have one entry and one exit point."

The EWR 127-1, Section 3.16, "Computing Systems and Software", provides an extensive list of "generic" software safety requirements, as does the AFISC SSH 1-1, "Air Force Engineering in Software Development." The Systems Safety Office and JPL Software Quality Assurance Section can provide guidance in identifying appropriate safety critical software requirements and developing a program for adequate monitoring of software development, testing and qualification.

2.11.6 EMI/ESD

The system design shall provide protection against harmful effects from electromagnetic radiation, or electrostatic discharge for the sensitive components of the SSCF computer system. For further requirements on ESD control see Section 4.2.9, Electrostatic Discharge.

Software Reuse

a. Re-used baseline software shall be evaluated to determine if it qualifies as an SSCF in accordance with paragraph 2.11.1.

b. SSCF re-used baseline software shall be analyzed for the following:
   1. Correctness of new or existing system design assumptions and requirements
   2. Changes in environmental or operational assumptions
   3. Impact to existing hazards
   4. Introduction of new hazards
   5. Correctness of interfaces with system hardware, software and operator

b. Unused or unneeded functionality in SSCF re-use baseline software and operator

c. SSCF re-used baseline software changes in system design, environment, or operation assumption shall be re-qualified or re-validated

d. SSCF re-use baseline software compiled with a different compiler shall be analyzed and tested

2.11.8 Commercial Off-the-Shelf Software

Software Safety Hazard Analysis shall be performed on all SSCF COTS software to verify such software is sufficiently safe.

2.12 PLANETARY PROTECTION

NASA Policy Guide NPG 8020.12B, “Planetary Protection Provisions For Robotic Extraterrestrial Missions” Specifies the requirements for all NASA robotic extraterrestrial missions “this document establishes basic NASA requirements for the biological protection of the major planets, asteroids and other solar system bodies that may be of interest in the exploration of our solar system and for the return of extraterrestrial samples to earth.”

“Implementation of these requirements will ensure that biological safeguards to maintain extraterrestrial bodies as biological preserves for scientific investigations are being followed in NASA’s space programs. In particular, this document is consistent with the biological contamination control objectives of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions and of Article IX of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, January 27, 1967, TIAS 6347 (entered into force October 10, 1967).”

SECTION 3

3 GROUND SUPPORT EQUIPMENT REQUIREMENTS

This section of the JPL Standard for Systems Safety document applies to the design, *material selection*, *fabrication*, *inspection and transportation* of Ground Support Equipment (GSE).
Test and handing requirements and proof-test and validation requirements are specified in Section 4.

3.1 APPLICABILITY

This document covers the design, material selection fabri cation, inspection, and transportation of ground equipment utilized in the support of JPL Critical Items (JCIs). The following types of equipment are covered; Mechanical support equipment, Test and Servicing equipment, equipment used in conjunction with radiation emitting JCIs and Software.

Mechanical Ground Support Equipment shall be designed *, fabricated, inspected and tested* in accordance with the requirements established in the latest version of JPL ES 501492 "Safety Requirements for Mechanical Support Equipment" and this section. Inspection, proof-test, functional test and use requirements are also specified in JPL ES 501492, *as well as Section 4 of this document.*

Note: (1) JPL document D-6904, titled Ground Handling Equipment Design Handbook, incorporates information on the design, fabrication, assembly, handling, and shipping equipment (AHSE). The document contains planning and control, drawing hints, and information on materials, surface treatment, welding, nondestructive inspection, fasteners, structural design, cryogenic-high-vacuum applications, and safety. It is strongly recommended that designs be in compliance with D-6904 as well as this document.

3.2 Explosion-Proofing

Explosion-proof connectors and equipment shall be used for circuits which can potentially be energized when an explosive environment either exists, or could exist in the event of a mishap. Circuits which are intrinsically safe by virtue of their low voltage and current levels need not be explosion proof (ref. NFPA 500- Hazardous Classified Locations).

3.2.1 *Use With Flammables:* Equipment intended for use with flammable solids, liquids, or gases shall be designed and fabricated using equipment with an explosion-proof rating per NFPA 70 National Electrical Code (KHB 1700.7).

3.2.2 *Use in Potentially Explosive Environments:* For equipment which is only incidentally employed in potentially explosive environments, the following techniques shall be employed to render the equipment hazard-proof . Techniques other than using explosion-proof-rated equipment shall be approved by the Systems Safety Office and by the appropriate outside safety organization if the equipment is used at a site other than JPL. The techniques are listed in order of preference:

(1) Hermetically sealing or potting.

(2) Inert gas purging.

(3) Inserting in an enclosure with a continuously supplied inert gas.

(4) Selective operation by a local attendant/operator only when an explosive atmosphere is verified not to exist. This method requires continuous presence by the attendant/operator and the ability to power-down the equipment with a single switch or power disconnect (see Section 4.7.3).

3.3 Center of Gravity

3.3.1 *Electronic Equipment Racks:* Electronic equipment racks used in System Test Complexes, Launch Complexes, or Launch Complex Equipment Trailers shall conform to the center of gravity requirements specified in JPL document ES 501492.

3.3.2 *Assembly and Handling Equipment:* Assembly and handling equipment shall conform to the lateral stability requirements of JPL document ES 501492. Proof-load or analysis tests shall demonstrate lateral stability.

3.4 Fault Tolerance

Wherever practicable, Ground Support Equipment, including equipment for test and evaluation which is not formally delivered to the project shall be designed to preclude damage to the flight equipment in the event of a single failure in the support equipment.

Specific functions or subsystems shall conform to specific fault tolerance requirements established for that function by the launch agency or other controlling agency.

3.5 Computer Controls

GSE that employs computerized/software controls of potentially hazardous activities shall explicitly define control functions in documentation of a step-by-step basis to the level of detail such that each function can be reviewed and potentially hazardous states can be identified.

Emergency flags shall be written in safing or shutdown procedures which shall be prepared. All personnel operating the equipment shall receive training on these procedures.

Computer software controls of hazardous GSE functions shall be evaluated for fault tolerance and designed for appropriate control. This includes situations where multiple software controls are used but are implemented on the same hardware, or software controls are employed on different hardware platforms that have a common single-point failure such as all hardware being connected to the same electrical power source. Backup mechanical or manual emergency safing functions shall be available. (See Section 3.11 for additional software safety requirements for GSE.)

Note: Special electronic racks designed to house GSE computer controls require careful review of the method of grounding. All receptacles used in new or re-built computer racks shall conform with the requirements of the NEC as well as the manufacturer's recommended grounding plan.

3.6 MATERIALS

Materials shall be compatible with the service fluids while operating in the worst case thermal pressure and corrosive environments expected throughout their intended service life.

3.6.1 Stress Corrosion

Materials resistant to stress corrosion shall be used in GSE which may be in contact with or provide support for JCI's. Specification MSFC-SPEC-522 design criteria for controlling stress corrosion cracking should be used as a guideline for the selection of acceptable materials. Materials from Tables I and II of that document are preferred.

3.6.2 Flammability

The following criteria shall be observed to provide protection of JCI equipment from internal and external fire damage.

Materials used in the manufacture, assembly, test, and packaging of essential electronic equipment shall be flame retardant under all conditions to which the equipment will be exposed. (Ref. ES 511335, Non-Flammable Material Requirements for GSE, Safety Practice SP 4-08-31 (legacy document), and NFPA-75, Electronic Computer/Data Processing Equipment Fire Protection For *Essential* Electronic Equipment.)

(2) As of this time, JPL Safety Practice documents are being transferred to JPL's electronic document file (DMIE) and the document numbers (i.e. SP 4-08-31) will be

revised. The documents will be located by their title.

3.6.2.1 *Specially Designed Equipment:* JPL-Critical Items (especially electronic equipment) which are designed and constructed especially for use by JPL shall make the maximum practicable use of nonflammable, fire-resistant, and fire-retardant materials.

Such equipment also shall be so designed and constructed to:

(1) Reduce, limit, or localize damage occurring to the individual piece of equipment in case of internal fire.

(2) Contain internal fires which may occur and thereby reduce the danger of spreading the fire to other equipment.

(3) Resist internal damage (or actual ignition) from exterior fires or extremely high external temperatures.

3.6.2.2 *Commercial Equipment:* Commercial equipment purchased for JPL use in critical or essential applications shall meet the above requirement to the maximum extent practicable. If the equipment is to be modified before use (or before reuse in a more recent application), modifications shall be made using nonflammable materials.

Note: Care shall be taken in all modifications of commercially purchased equipment to avoid nullifying the manufacturer's warranty or any UL or equivalent ratings.

3.6.2.3 *Cables:* Cables for use at the system (spacecraft or experiment) level shall be constructed of flame-retardant materials or, at the minimum, shall be fully covered with flame-retardant materials. *All cables that run through air handling ducts or plenums shall be plenum rated.*

3.6.2.4 *Wooden Pallets and Containers:* Pallets, shipping or storage containers, or any other items manufactured of wood or wood-based materials which are used in conjunction with or in close proximity to JCI's shall be treated with fire-retardant paint as specified in D-6904. Use of a fire retardant wrap on wood or wood-based materials in lieu of paint is acceptable at JPL, however, it may require a waiver for use at KSC.

3.6.2.5 *Pressure Systems Materials:* Materials chosen for ground support equipment pressure systems shall be selected with the protection of personnel and the JCI in mind. *Materials selected for use in pressure systems shall be compatible with the internal and external service fluids. Many materials can react violently with oxidizing gases and liquids and with high pressure air or act as a catalyst causing decomposition.*

3.6.2.5.1 Reactive Fluid Systems: Materials selected for use in reactive fluid systems shall be verified to meet the following:

(1) Compatible with the specific fluids over the potential temperature range of GSE use and storage.

(2) Chemically and particulate clean to the level appropriate for the specific application.

3.6.2.5.2 Propellant System: Materials acceptable for use in Propellant handling GSE are generally the same as those acceptable for flight systems (refer to Section 2.6.5).

3.6.2.5.3 Nonmetallic Pressure Components: The use of nonmetallic pressure. Retaining components shall be approved on a case by case basis by the JPL Pressure System Safety Manager and the System Safety Office.

3.7 MECHANICAL SUPPORT EQUIPMENT

3.7.1 Design Load Factors

Cranes, ground support equipment, fixtures, handling equipment, or shipping and transportation equipment shall be designed and tested in accordance with JPL document ES 501492 *and section 4 of this document*. During proof-test, the test load shall be applied along a line through the center of gravity of the JCI which the equipment was intended to support.

Design load factors for GSE shall be establishe d using the criteria as set forth in ES 501492 for each specific piece of equipment.

3.7.2 Lifting, Elevating and Handling Equipment

3.7.2.1 *Cranes and Hoisting Mechanisms:* All cranes and hoisting mechanisms shall be designed, inspected and tested in accordance with the following in addition to this document:

a. JPL Safety Practice " Lifting and Elevating Equipment" (4-08-25 legacy document)

b. ES 501492 Sections 3-7 & 14

Cranes and hoisting mechanisms, including all attached rigging, used in the movement of JCIs' shall be visually inspected prior to use. A pre-lift inspection shall be completed addressing the following;

a. Cables, wire rope, hooks, hasps, slings etc. shall be appropriately marked or tagged with the maximum working load and inspected for damage. Smashed, kinked, frayed, or otherwise damaged cables or other such equipment shall not be used and tagged out.

b. All lifting equipment shall be inspected for evidence of oil leakage.

c. Mechanically and electrically operated brakes shall be inspected and functionally tested according to the manufacturer's recommendations prior to lifting a JCI.

d. If any repairs or modifications are made to important structural components of a crane, the crane shall be re-inspected and proof tested prior to use.

e. All hooks shall have approved safety latches which shall be inspected for damage prior to lifting operation.

3.7.2.2 *Design:* The following structural considerations shall be employed in the design of JCI fixtures or handling equipment:

Note: Qualification by test (supported by appropriate NDE) without a supporting analysis is acceptable.

(1) Structural strength shall be adequate to sustain the static and dynamic loads applied to the fixture or equipment under worst case conditions including any point loadings due to attachments.

(2) Structural stiffness shall be adequate to prevent deformation which might induce unwanted local loads into the flight equipment structure or which might compromise the functional ability of the fixture or equipment during all expected environments.

(3) Lifting fixture overturning moments, proof load, and center of gravity constraints shall be in compliance with ES 501492.

(4) Natural fiber rope shall not be used in fixtures to lift or elevate JCI's.

3.7.2.3 *Protection*: Subsystem handling fixtures shall be designed to effectively and safely function with the equipment for which they are provided.

3.7.2.4 *Materials:* Handling fixture materials shall be heat resistant to 71 ^{o}C (160^{o}F) and resistant to lubricants, solvents, or other environments within which they may be used. (see also Section 3.3).

3.7.3 Cable Harness Fixtures

Cable harnesses shall be retained as close to their original fabrication configuration as practicable for shipment and storage. *Kinked or frayed cable shall not be accepted*.

Cable harnesses that are fabricated on three -dimensional fixtures shall be transported and stored on either the fabrication fixture or on a shipping fixture fabricated specifically for this purpose.

3.7.4 Storage, Shipping, and Transportation Equipment

3.7.4.1 *Fabrication and Local Storage:* The following design criteria as a minimum shall apply to fabrication fixtures and storage containers used for JCIs:

(1) Shock and vibration dampening devices shall be incorporated if the hardware could be damaged by these environments.

(2) Shock and vibration monitoring devices shall be incorporated into the container, if the hardware is sensitive to these environments.

(3) A moisture seal shall be incorporated if the hardware could be damaged degraded by exposure to the ambient environment and is not otherwise protected against moisture.

(4) Internal attachment support devices, incorporated as an integral part of the container design, shall be provided to the maximum extent practicable.

(5) If the equipment is moisture sensitive, a desiccant chamber, or other drying medium, shall be utilized in all equipment voids.

(6) Insulating materials for protection against excessive heat shall be flame resistant and appropriate for the degree of protection required by the particular equipment.

(7) Materials used in the fixtures and containers shall not be susceptible to electrostatic charge build-up if the hardware is ESD sensitive, or if the fixture/container is used to transport the hardware into ESD-controlled areas such as the spacecraft assembly area. Materials with inherently conductive or non-charge generating properties are preferable to treatment with topical anti-stat agents.

(8) Metal surfaces shall be protected against environmental or galvanic corrosion. Sacrificial anodes should be employed where galvanic or stray current corrosion is unavoidable.

(9) There shall be no sharp points or burred edges that could cause injury to personnel or damage to the hardware.

(10) Materials shall not outgas or otherwise contaminate the hardware. This must be considered even if the specific hardware is not sensitive to the contamination.

(11) Specific consideration shall be given in the container design to preclude blocking container hardware vents or breathers (i.e. battery vent caps)

(12) Consideration shall be given to the storage of the container itself during non use time periods to avoid possible damage from external mechanical or environmental sources.

3.7.4.2 *Transportation:* The following requirements shall be applied to containers used for transportation of JCIs:

(1) The container shall be available for use in the first and all subsequent shipments of JCI's.

(2) The design shall permit safe packing and unpacking without functional damage to the fixture or the equipment itself *or hazards to personnel involved in the unloading process.*

(3) The size, shape, and weight of the container shall be consistent with the requirements of the intended mode of transportation.

(4) The structural materials shall be resistant to impact, fire, and stress. Reinforced plastics are acceptable if precautions are taken to prevent electrostatic buildup and contamination. Outgassing properties of the materials shall be considered in their selection.

(5) Container materials shall be resistant to oil and water absorption.

(6) Container materials and surfaces shall be easy to clean. The container shall be as light in weight as safety factors and practicability permit consistent with hardware protection requirements.

(7) Metal surfaces shall be protected against galvanic an d environmental corrosion.

(8) The container shall have no sharp points or burred edges that could cause injury to personnel or damage to hardware.

(9) Shock absorbing or vibration damping devices or material shall be used to protect delicate or sensitive equipment. Monitoring devices shall be included for particularly sensitive equipment.

(10) Gripping devices or handles shall be firmly fastened to the container to facilitate ground handling. Fixed hoisting or fork-lifting attachments, when required, shall form an integral part of the container design.

(11) Sealed containers shall have a pressure release system. Operating instructions shall be posted conspicuously on the outside of the container. As a minimum, the design of a sealed system shall have a safety factor of 4 on ultimate stress under all conditions that might be encountered. Containers which will be exposed to differential

pressures exceeding 103.4 kPa (15 psi) shall require specific approval of the design by the **JPL Pressure Systems Manager**.

(12) Packaging materials such as "bubble wrap " shall be verified as non static chargeable and shall not exert excessive force on flight hardware due to expansion throughout the expected pressure range of the transportation environment.

(13) Containers used for the shipment of JCI's shall be designed and qualified in accordance with the requirements of D-8208 Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling (DM 509306).

(14) All flammable containers shall be protected with fire-retardant paint per D-6904.

3.7.4.3 *Container Identification*: The shipping containers for all JCI's shall be identified with shipping instructions and distinctive markings as follows;

Note: System-level shipping containers (spacecraft) which will never be unescorted during movement are exempt.

3.7.4.3.1 Instructions. A transparent plastic envelope shall be attached to one of the four vertical sides of each shipping container. The envelope shall contain a card with the word "EMPTY" printed on one side and the following information on the other (see Section 3.4.5.1 (7) for ESD concerns):

(1) Notification of ownership.
(2) Destination.
(3) Who may open the container.
(4) Temperature limits.
(5) Humidity/contamination restrictions for opening.
(6) Shock or vibration level limitations.
(7) Any time-critical factors.
(8) Any hazardous materials notifications, limitations, identifications, etc.
(9) Ionizing/non-ionizing radiation restrictions.

When a container is empty, the reversible card shall be turned so that the word "EMPTY" is displayed.

Note: Containers with hazardous materials shall be clearly identified and comply with design and handling requirements of the appropriate DOT regulation.

3.7.4.3.2 Distinctive Markings: Containers for JCI's shall have the four top corners painted on the outside of the container with solid bright international orange. The extent of the triangular shaped area at each of the top corners shall be in accordance with ES 501492.

3.8 TEST EQUIPMENT

Commercial and special test equipment, whether used individually or integrated into an equipment rack containing several pieces of test equipment, shall conform to the following requirements.

3.8.1 Power Cables

Input power cables and connectors shall be conservatively rated, employ safe ty ground wires, and shall not have any exposed wires. All electrical power cords shall conform to the requirements of JPL Policy "Electrical Safety" as well as the JPL Facilities Design Standard Section 8.

3.8.2 Connectors

3.8.2.1 *Connector Savers:* Connector savers shall be attached to JCI connectors at the earliest opportunity in order to protect the JCI from wear and tear due to repeated mating with non-JCIs. The connector saver shall consist of a flight quality connector which mates with the JCI, a short length of cable and a "workhorse" connector which will mate with the non-JCI.

3.8.2.2 *Connector Keying:* Multi-pin connectors supplying power or signals to any part of the flight equipment shall be sized and/or keyed to prevent incorrect insertion or connection of wrong connectors. Mechanical and electrical analysis shall be performed to eliminate any possible misconnection.

3.8.3 Racks

Each test equipment rack shall employ transformer isolation between the facility power mains and all equipment within the rack. The secondary of all power isolation transformers shall be referenced to ground.

3.8.4 Lockout-Tagout

Whenever work is to be performed on an electrical circuit, motor, or motor driven equipment used in the testing of JCIs, lockout/tagout procedures shall be utilized as described in the JPL Lockout/Tagout Policy.

3.9 SERVICING EQUIPMENT

The Jet Propulsion Laboratory is subject to Federal and State Safety Codes and

Regulations for pressure vessels and pressurized systems used in support operations whether installed for temporary use or permanently installed. It is mandatory that proper precautions be observed when designing fabricating and testing all GSE utilizing pressurized hardware before the equipment is placed in service.

For all pressure systems where the Maximum Operating Pressure (MOP) exceeds a gauge pressure of 103.4 kPa (15 psig), the following precautions shall be taken.

3.9.1 Pressure Vessels

3.9.1.1 *Design Requirements*: Non-flight pressure vessel designs shall conform to one of the following:

(1) ASME Boiler and Pressure Code , Section VIII, "Unfired Pressure Vessels." Divisions I or II.

(2) Code of Federal Regulations, Title 49, "transportation," for vessels used in traffic under the jurisdiction of the Department of Transportation (DOT).

(3) Other criteria specifically allowed by the JPL Policy “Pressure Vessels and Systems”.

Note: Even though devices specially fabricated from pipe, tubing, etc. are not technically pressure vessels, they shall be reviewed by the JPL Pressure Systems Safety Manager for acceptable design and fabrication criteria.

3.9.1.2 *Fracture Mechanics*: A fracture mechanics evaluation shall be required on all non-code stamped or DOT stamped GSE pressure vessels. This evaluation shall be performed for each combination of internal and external pressure fluids and vessel materials to be used. This requirement shall also apply to all code stamped and DOT stamped (approved) vessels on a case by case basis as required by the project or as directed by the JPL Pressure Systems Safety Manager. This is a JPL requirement and not governed by state regulation. The fracture mechanics analysis shall be performed on all vessels under the direction of the JPL Structures and Materials Review Committee.

3.9.1.3 *Special or Experimental Vessels:* Special or experimental pressure vessels and equipment which may be required in advanced technology shall be designed and built in accordance with the applicable ASME code, and subjected to fracture mechanics analysis as specified in 3.6.1.2.

3.9.1.4 *Drawings:* The following statement shall appear on the appropriate pressure vessel engineering drawings:

THIS PRESSURE VESSEL SHALL CONFORM TO ASME BOILER AND PRESSURE VESSEL CODE, SECTION VIII,

DIV _____ UNFIRED PRESSURE VESSELS." REPAIRS AND MODIFICATIONS TO PRESSURE VESSELS OR PRESSURE SYSTEMS SHALL CONFORM TO CODE REQUIREMENTS. MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP) SHALL NOT EXCEED _____ PASCALS (_____ LB. PER SQUARE INCH (GAUGE)) WITH ___ (GAS/LIQUID). PRIOR APPROVAL OF THE JPL PRESSURE SYSTEMS SAFETY MANAGER SHALL BE OBTAINED FOR USE WITH ANY OTHER COMPRESSED GAS OR PRESSURIZED LIQUID.

In addition, the following information shall be included as part of the notes of the appropriate pressure vessel drawing or included in the code data book:

(1) Allowable operating fluids.

(2) Allowable test fluids, such as those for internal and external cleaning or hydrostatic testing.

(3) Maximum Allowable Working Pressure (MAWP). Based on design or material.

(4) Normal and maximum allowable operating pressure and temperature ranges.

(5) Proof pressure and temperature.

(6) Burst pressure (derived by analysis).

(7) Planned and allowable number of pressure cycles.

3.9.1.5 *Life History:* A life history log book shall be compiled and maintained for each GSE pressure vessel in use at JPL. The log shall contain the following information as a minimum:

(1) Date of test or activity.

(2) Fluids or gasses involved.

(3) Maximum pressure & temperature attained.

(4) Cumulative pressure cycles.

(5) Test personnel.

3.9.1.6 *Procurement:* JPL does not possess ASME authorization to fabricate coded pressure vessels; therefore, all coded pressure vessels shall be procured in accordance with the appropriate provisions of the JPL Policy “Pressure Vessels and Systems. The JPL Pressure Systems Manager maintains the standard information and wording for the pressure vessel procurement specification and shall be involved in the procurement.

3.9.1.7 *Repairs:* Repairs, replacements, or other modifications to coded or non-coded pressure vessels shall be documented and the design approved by the JPL Pressure Systems Safety Manager prior to changing the hardware.

3.9.1.8 *Proof Test*: GSE pressure vessels and systems shall be proof tested prior to being put in service and periodically re-tested following the guidelines of NASA NHB 1700.6, "Guide for In-service Inspection of Ground Based Pressure Vessels and Systems." This testing shall be accomplished in accordance with the JPL Safety Operations Section In-service Inspection (ISI) Program specified in Safety Policy "Pressure Vessels and Systems".

3.9.2 Pressure Systems

Ground support systems designed and built by or for JPL shall comply with the following requirements:

Pressure systems for ground support equipment shall be designed, fabricated, assembled, inspected, tested and maintained in conformance with the appropriate state regulations (i.e. California Administrative Code, Title 8, Chapter 4, Subchapter 1).

Compliance with JPL Policy "Pressure Vessels and Systems" is required.

Compliance with NASA Policy Document NPD 8710 – "Safety Policy for Pressure Vessels and Pressurized Systems" (replaces NMI 1710).

Pressure vessels shall conform to the requirements of Section 3.6.1 of this document

3.9.2.1 *Hazard Rating:* Pressure systems shall be designated as HAZARDOUS and SAFETY CRITICAL. (see Section 1.8 of this document)

3.9.2.2 *Procedures:* Maintenance, inspection, testing, and operation of GSE pressure systems shall be performed with an approved procedure.

3.9.2.3 *Proof-Test:* GSE pressure systems shall be proof tested to a minimum of 1.25 times the Maximum Operating Pressure (MOP) prior to placement of the system into service. The MOP of pressure vessels included in the system shall be selected to permit this proof-test or isolated and tested separately if MAWP of the vessel is lower than the MOP of the system.

Proof-test information shall be included in the documentation and certification for each piece of equipment tested.

3.9.2.4 *Markings:* Ground servicing equipment pressure lines (flexible or rigid) shall be permanently identified, tagged, or marked with the maximum pressure to be carried, and the proof pressure and date. See Section 4.3.1.6.1 for flexible-line proof-test requirements.)

3.9.2.4.1 Information. Pressure lines external to a console or other cabinet shall be marked with the following information:

(1) Function (fluid service).

(2) Proof pressure date of test.

(3) Maximum Allowable Working Pressure (MAWP).

3.9.2.4.2 Location: The pressure line markings shall be within 30 cm (1 foot) of each connection or component (valves or regulators) with additional markings each 3 meters (10 feet) of line. For long partially concealed lines, the marking should be easily visible anywhere the line is exposed to the working area. This may require additional markings.

Where several hard lines make up a bank or control subsystem, one label showing the maximum allowable working pressure is sufficient.

All labels and markings should be resistant to environmental exposures including weather, cleaning agents and operating fluids

3.9.2.4.3 Console: Consoles or assemblies shall have piping schematics which include markings to show directions of
flow, on/off positions of control devices, relief device locations and settings, and maximum allowable working pressures.

3.9.2.5 *Flexible Line*: The following requirements shall be observed for all flexible lines in support of flight or project-critical equipment. Due to the inherent hazards of flexible lines, they should be used only when hard lines cannot be utilized.

3.9.2.5.1 Proof-Test: Flexible lines that will be used at pressures above 103.4 kPa (15 psig) shall be proof-pressure tested per Section 4.3.1.6.

3.9.2.5.2 Proof-Test Tags: Flexible lines shall be labeled and a proof test tag attached (see Section 4.3.1.6.1. for tag information).

3.9.2.5.3 Tie-Downs: Flexible lines operating under pressure shall be anchored at each fitting and also at 1.8 meter (6 foot) intervals (maximum). The anchors may be either structural tie-downs or weights. The weight shall be sufficient to prevent the line from whipping should a rupture or end fitting separation occur. In the case where shot or sand bags are used for weights, care shall be taken to ensure that the bags have not leaked and that the weight is as expected.

3.9.2.6 Gauges: Visual gauges which can be pressurized above atmospheric pressure shall comply with the following requirements:

(1) Pressure gauges shall be of one-piece, solid-front construction with blow-out backs and shall have an optically clear shatter-proof window.

(2) Gauge ranges shall be selected so that the principal use of the gauge is in the middle 50 percent of its range.

(3) The operating pressure shall not exceed 75 percent of the highest gradation.

(4) Gauges shall not be used for controlling safety-critical pressures at less than 25 percent of the full-scale pressure.

(5) Gauges shall have certification labels or be marked “For Reference Only.”

Note: Pressure gauge range requirements are not applicable to vacuum gauges .

3.9.2.7 *Safety Factors:* Components, except pressure gauges and relief devices, but including tubing and fittings, shall have a burst pressure rating of at least four times the operating pressure if persons are present after pressurization.

3.9.2.8 *Overpressure Relief:*

3.9.2.8.1 Downstream of Regulators: The system downstream of regulators shall be protected by relief devices unless the system is capable of withstanding full upstream pressure with appropriate factors of safety.

3.9.2.8.2 Entrapped Fluids: Relief devices shall be installed in all closed sections of the pressure system or in sections which can be isolated by the closing or operation of valves if trapped fluids could increase in pressure beyond the safe working limits of the system due to temperature increases or other plausible reasons.

3.9.2.8.3 Size: The relief inlet and vent ports shall be adequately sized so that the system pressure does not exceed MAWP during upset condition due to limited flow capacity. A good rule of thumb is to size the relief inlet and vent ports the same size as the line the relief valve is connected to (minimum).

3.9.2.8.4 Relief Device Settings: Relief devices shall be set to crack at a pressure not to exceed the following:

PRIMARY RELIEF DEVICE SETTINGS (MAXIMUM)

Type of System	Crack	Full-open
ASME Pressure Vessels	100% (MOP)	110% (MOP)
Pressure Systems (without pressure vessels)	110% (MOP)	120% (MOP)

SECONDARY RELIEF DEVICE SETTINGS (MAXIMUM)

Type of System	Crack	Full-open
ASME Pressure Vessels	105% (MOP)	110% (MOP)
Pressure Systems (without pressure vessels)	110% (MOP)	120% (MOP)

3.9.2.8.5 Relief Valve Discharge: Potentially hazardous discharge from relief devices shall be routed to areas or disposal systems into which it is safe to discharge the system effluent. Incompatible effluents shall not be commingled in the vent system.

Relief valves shall be suitably supported to avoid discharge stress risers on the equipment they are attached to.

3.9.2.8.6 Failure Tolerance: The GSE/flight equipment interface shall be protected by at least two pressure relief devices downstream of the last regulator. One of these devices must be a relief valve, the other may be a relief valve or a burst disk.

3.9.2.9 Mismating of Connections: Fuel, oxidizer, and common pressurant systems shall be designed so that cross-connection of incompatible systems is not possible. Lines for each of these systems shall be sized, located physically, and clearly marked in such a manner that inadvertent cross connection is not possible.

Fittings and fitting components such as cone seals and compression sleeves on compression type fittings shall be of the same make and installed in accordance with the manufacturer's recommendations. Fittings and fitting components of a different manufacturer shall not be mixed.

3.9.2.10 Drawings: The hardware responsible engineer shall ensure that the following information is included as part of the notes on the appropriate drawing(s):

(6) Allowable operating fluids.

(7) Allowable test fluids (such as those used for cleaning and hydrostatic testing).

(8) Allowable operating pressures.

(9) Allowable operating temperature range.

(10) Proof pressure. And date of proof test

(11) Design burst pressure.

(12) NDT/NDE inspection level requirements.

3.9.2.11 Bonding: Pressure vessels, components, and tubing within a pressure system containing explosive or flammable fluids or gases shall be electrically bonded and grounded.

3.9.2.12 Low Points: Care shall be taken to provide for complete drainage of fluid systems by avoiding low points where fluids can remain during draining operations. Where such low points are unavoidable, drain plugs or valves shall be provided.

3.10 RADIATION

3.10.1 General

Ground Support Equipment which is used in conjunction with radiation-emitting JCI's or which can emit radiation, shall be designed, operated, handled, and stored in accordance with the appropriate sections of the JPL Safety Manual (legacy document). The following sections of the Safety Manual should be reviewed for applicability:

SP 4-08-41	"Radio Frequency Transmitters"
SP 4-08-50	"Radiation Safety Organization Duties and Responsibilities"
SP 4-08-51	"Radioactive Materials and Radiation Areas"
SP 4-08-52	"Radioactive Contamination"
SP 4-08-53	"Radioactive Materials/Radiation Machines - Acquisition and Transportation"
SP 4-08-54	"Design and Construction of Radiation Facilities"
SP 4-08-55	"Laser Hazards And/Operations"
SP 4-08-56	"Ionizing Radiation - Operation of Radiation Producing Equipment"
SP 4-08-57	"Radiation Monitoring Instruments"

When JPL's electronic document system (DMIE) is fully implemented, it is planned that the Safety Practice numbers (i.e. 4-08-41) will be deleted and the documents will be located by their title.

3.10.1.1 *Radiation-Emitting GSE:* Ground Support Equipment which emits either ionizing or non-ionizing radiation shall be designed to minimize the release of radiation to the environment.

3. 10.1.2 *Ground Support Equipment for Radiation-Emitting Hardware:* Ground Support Equipment interfacing with radiation-emitting hardware should be designed to minimize personnel exposure to radiation (ALARA).

3.10.2 Placarding

Ground Support Equipment whose radiation could be harmful shall have warning placards conspicuously attached to the equipment. The following information shall, as a minimum, be included on the placard:

(1) Type of radiation.

(2) Field strength or intensity as a function of distance from the equipment.

(3) Personnel exposure limitations.

3.10.2.1 *Ionizing:* Ground Support Equipment and test equipment containing ionizing radiation sources shall be approved by the Radiation Safety Committee.

3.10.2.2 *Non-Ionizing:* Ground Support Equipment and test equipment which emits any form of harmful non-ionizing radiation at potentially harmful levels shall be reviewed and approved by the JPL Safety Operations Section and the Radiation Safety Committee.

3.11 SOFTWARE

Safety must be designed into software from the beginning. The following shall be included in the overall system design.

3.11.1 Inhibits

Safety-critical functions shall include non-computer-controlled inhibits which will preclude the inadvertent occurrence or command of that function in the event of a computer hardware or software failure.

3.11.2 Hazard Analysis

A Software Hazard Analysis shall be performed on software containing safety-critical functions. The effects of command, input, and processor timing shall be included in the analysis.

3.11.3 Displays

Systems containing data displays which, if displaying erroneous data, could cause an operator to take action which could be harmful to flight equipment or hazardous to personnel shall be subjected to a hazard analysis (Section 3.8.2).

SECTION 4

4 TEST AND OPERATIONS REQUIREMENTS

This section defines specific constraints and requirements for the protection of personnel and safe conduct of handling, assembly, test, inspection, transportation, and storage of flight and project-critical hardware. See Section 1, paragraph 1.3.2 for the detail role of Systems Safety in the management and execution of Projects and Tasks. This role is reflected in each Project Safety Plan. The regulatory role of Systems Safety must have Project/Task Manager response. The advisory role of Systems Safety may elicit a Project action but does not require response from the Project/Task Manager.

Design requirements are contained in Sections 2 and 3

4.1 GENERAL

4.1.1 Applicability

The requirements of Section 4 shall apply to JPL Critical Item (JCI) operations at all levels of assembly, at JPL and non-JPL facilities, as long as JPL is responsible for the safety of the personnel or hardware. This includes JPL activities at subcontractors, other NASA centers, universities, non-USA and other facilities where JPL is responsible for the hardware.

Note: This requirement is not applicable when complete responsibility for the JCI is transferred to another agency by contract; i.e., delivery of an Instrument built <u>for</u> GSFC or MSFC or turn over by a DD1149. This requirement does <u>not</u> terminate if the instrument is delivered to GSFC or MSFC for integration of the JPL instrument into a larger payload (e.g. ATLAS, UARS, Space Station, EOS), but remains a JPL instrument.

Special precautions shall be taken to protect Project-Critical GSE, but it is not intended that it be treated with all precautions required for the flight equipment itself (refer to Section 1.7 for definitions).

Piece-part and component procurement lead times have grown significantly in recent years, and fewer items are procured as spares. This situation makes some GSE, including piece-parts and components, project-critical and requires the utmost in care for all phases of hardware handling and test.

The Cognizant Hardware Section Manager or Project Element Manager is responsible for the determination of "Project-Critical" status for GSE (Ref. 1.8). The Cognizant Engineer is responsible for specifying how "Project-Critical" hardware under his/her cognizance is to be protected (e.g. see applicable paragraphs from this Safety Standard, Section 4). The Project office shall concur with the "Project-Critical" designation as defined in the System Safety Plan.

Adherence to Section 4 is recommended for GSE which has not reached the level of project-critical, including special handling equipment such as proof load fixtures, personnel work stands, etc.

Note: The requirements for GSE computer controls and for GSE software which are stated in Sections 3.5 and 3.11 of this document are also applicable to test, handling, assembly, transportation, other project-critical equipment, facilities, and operations.

4.1.2 Notification

The following offices and departments shall be notified of flight activities and hardware status.

4.1.2.1 *Systems Safety Office:* The Cognizant Hardware Engineer, the Project Element Manager or the Project Test Conductor shall notify the Systems Safety Office sufficiently in advance of all JCI hardware transportation or hazardous test activities to permit the SSO attendance at planning meetings and reviews.

4.1.2.2 *Fire Department:* The Hardware or Facility Manager shall notify Plant Security and Fire Departments of the presence of JCI hardware in a facility, and of any special constraints to be followed to protect the hardware in the event of a fire (or the actuation of a fire alarm) in the facility. Notification shall also be made when the special constraints are no longer required.

4.1.3 Proof-Testing and Validation of Handling Equipment

Equipment involved in the handling and transportation of flight hardware shall be inspected and tested per the requirements of the following sections. JPL Specification ES 501492 defines the detailed requirements.

4.1.3.1 *Frequency:* A thorough inspection and verification of JCI handling equipment, including evidence of proof testing, shall be made prior to the start of the flight hardware handling operation in accordance with the requirements of ES 501492.

The checkout period may be extended to a maximum of six months prior to operations if the equipment is maintained in a controlled area where it is protected from undesirable environments and unauthorized use.

This validation process shall be repeated at least every six months for equipment which is subject to excessive wear or damage but, at least, annually.

4.1.3.2 *Inspection:* JPL Specification ES 501492 defines the specific, periodic inspection requirements for JCI handling equipment. A copy of the inspection report or P/FR identifying discrepancies discovered during inspection after the equipment is placed into initial service, and the corrective action, shall be forwarded to the **Systems Safety Office.**

Note: Use locations, such as KSC, ETR, WTR may have specific test and inspection criteria That shall also be complied with. In case of conflicting requirements, the more stringent shall apply.

4.1.3.3 *Reporting:* Inspection, verification or testing information generated in evaluating equipment for JCI handling shall be recorded and retained until the equipment is destroyed, surplussed, or otherwise disposed of.

4.1.3.4 *Failures*: In the event of an equipment failure during test or use, approval from the Systems Safety Office shall be required prior to further use of the equipment for handling JCI's.

4.1.3.5 *Placards*: The support equipment rated load, proof load, safe load, date of proof-test, and expiration date shall be indicated on a tag (JPL Drawing No.10025963 or equivalent) conveniently and conspicuously attached to the support equipment. In addition, a nameplate per JPL Drawing 10001658, shall be attached to all MGSE.

4.1.3.6 *Cranes and Hoists:* JPL Specification ES 501492 (latest revision) defines crane proof-test and inspection requirements in detail and shall be rigorously followed.

4.1.3.6.1 Frequency: Cranes shall be inspected and proof-tested immediately prior to initial use with JCI's (See Paragraph 4.2.3.1 for crane proof frequency). Cranes and other lifting devices or equipment attached to a facility shall be carefully checked for potential damage prior to use after an earthquake (see Section 4.1.3.6.6). Attachment points to the facility, rail alignment, and bridge/trolley rollers or wheels shall receive careful inspection.

4.1.3.6.2 Proof-Test Factors. Cranes used for handling JCI's shall be proof -tested to the test factors specified in ES 501492, SP 4-08-25, CCR: Title 8 (CAL OSHA), and NSS/GO-1740.9, This factor is summarized as follows:

- Maximum proof load value (125% of the nameplate value) applied at the payload/MGSE Interface. Maximum accelerations and worst case conditions shall dynamically applied for a minimum of 3 minutes.
- The equipment may be used at up to 1/2 of its proof tested value.

- In no case shall the proof-load exceed the crane manufacturer's operating load rating x 1.25.

4.1.3.6.3 Method: Cranes and lifting equipment shall be proof-loaded to the requirements specified in ES 501492 prior to use with JCI's. As a minimum, this test shall include:

(1) Visual inspection.

(2) Dynamic tests of lifting and braking mechanisms at maximum possible speeds.

(3) Traversing the entire travel in all directions with the proof-load attached.

(4) Shut off of the main power switch.

4.1.3.6.4 Placards. Placards indicating the maximum JCI weight to be lifted by the crane shall be placed on the control pendant/panel. The placard shall be worded so that the maximum allowable JCI weight cannot be confused with the crane manufacturer's rating. The crane Certification Certificate shall be conspicuously posted.

4.1.3.6.5 Repair: Repairs or modifications to the structural members of a crane system shall be approved by the **Safety Operations Section**.

(1) Replacement cables shall be proof tested in accordance with the requirements of CCR: Title 8 (CAL OSHA) and NSS/GO-1740.9

(2) The load tests shall be repeated each time a load-critical piece of equipment is replaced (cable, hook, etc.).

4.1.3.6.6 Earthquake Inspection. Following an earthquake, and when it is safe to do so, cranes and other lifting and hoisting equipment which are structurally attached to a facility shall be inspected for structural changes or damage (Also Refer to Section 4.4.7).). Depending upon the quake intensity, an Emergency Disaster Response Team (consisting of the JPL Fire, Emergency Preparedness and Facilities Departments, the Systems Safety Office and Safety Operations Section) will make an immediate safety assessment of buildings and notify Building Wardens of hazardous conditions. Facilities will provide a Registered Engineer to assess the scope of refurbishment.

As a minimum, the team will:

(1) Inspect all lifting equipment attach points to the facility for cracks, looseness, or distortion/yielding.

(2) Perform a full range operational checkout with specific attention to unusual sounds or motions during travel. This checkout may be

made with the lifting hook either unloaded or lightly loaded with a ballast weight.

If problems are noted in items (1) or (2), or if other facility structural damage is noted, then items (3) and (4) shall be performed:

(3) Inspect all bridge and/or trolley rails for alignment or signs of distortions or yielding.

(4) Inspect all wheels and rollers supporting the lifting assembly in the bridge, trolley, or rails for distortion, yielding, fracture, or other damage.

Re-proofloading of the crane or lifting equipment shall not be required unless evidence of damage is revealed during the inspection and operational checkout process.

Note: Light-rolling types of quakes probably do not require crane inspections, but larger motions or sharp jolt types do. If the motion is sufficient to displace typical items sitting on flat surfaces, the lateral forces indicated by such displacement range from less than 0.1g to more than 0.5g, depending on the materials and surfaces involved. Such lateral loads in a crane system designed primarily for vertical loads can easily exceed the crane and facility design lateral load capability. A suggested guideline for determining the need for inspection is that if displacement of such typical items as boxes, crates, tables, chairs, etc., has occurred, the inspection should be performed.

4.1.3.7 MGSE and Assembly, Handling and Shipping Equipment. JPL Specification ES 501492 defines the proof test requirements in detail and shall be rigorously followed. The following loads shall be applied at, or through, the center of gravity of the item being tested:

4.1.3.7.1 Proof-Test Factors. JCI hardware handling equipment shall be proof tested per ES 501492 using the following factors:

1. Dynamic: 2.0 x JCI hardware weight + equivalent weight of MGSE (fixtures, slings etc.). The dynamic proof load test shall be performed using maximum accelerations and worse case conditions. The proof load shall be held for a minimum of 3 minutes.

2. Static: 3.0 x JCI hardware weight + 2 times the equivalent weight of MGSE (fixtures, slings, shackles etc.). The proof load shall be held for a minimum of 3 minutes.

4.1.3.7.2 Side-Load Test Factors. Handling equipment which may at any time receive side loads shall be shown by analysis or test to be capable of withstanding side loads (horizontal direction). The side load for test shall be 0.25 times the dynamic proof-test load (0.44 times the JCI equipment rated load).

The side load shall be applied simultaneously with the vertical proof-test load.

4.1.3.7.3 Shackles, Bolts, Fittings. Shackles, Bolts, Fittings etc., must be marked in such a way so that they are always used in the same location in the lifting/handling configuration as assembled in the proof test.

4.1.3.8 Miscellaneous Equipment.

4.1.3.8.1 Hydra-Sets. Hydra-Sets shall meet the same annual proof-load testing criteria applied to all other JPL lifting and handling equipment.

Dynamic Proof Test. A proof load of up to the manufacturers maximum proof load value shall be applied at the payload/MGSE interface with the piston bottomed out. Using maximum acceleration and worse case conditions, the proof load shall be held for a minimum of 3 minutes. The equipment can be used at up to 1/2 of its proof tested value provided that a minimum ultimate factor of safety of 5 is maintained.

Static Proof Test. A proof load of up to the manufacturers maximum proof load value shall be applied at the payload/MGSE interface with the piston bottomed out. The proof load shall be held for a minimum of 3 minutes. The equipment can be used at up to 1/3rd of its proof tested value provided that a minimum ultimate factor of safety of a 5 is maintained.

Hydra-Set Seal Test. With a test load between 90% and 100% of the Hydra-Set's capacity (not to exceed 100%), operate the unit to approximately the midstroke position. Using a dial indicator or equivalent, verify that the load does not move up or down by more than .005 inches in 5 minutes.

Hydra-Set Calibration. Hydra-Sets' shall be calibrated after each proof test. Refer to Section 4.2.3.3 of this Standard for the type of Hydra-Set to be used when handling JCI's.

4.1.3.8.2 Load Cells. Load cells shall be annually proof-tested using either of the following methods:

Dynamic Proof Test. A proof load of up to the manufacturers maximum proof load value shall be applied at the payload/MGSE interface. The proof load shall be held for a minimum of 3 minutes. The equipment can be used at up to ½ of its proof tested value provided that a minimum ultimate factor of safety of 5 is maintained.

Static Proof Test. A proof load of up to the manufacturers maximum proof load value shall be applied at the payload/MGSE interface. The proof load shall be held for a minimum of 3 minutes. The equipment can be used at up to 1/3rd of its proof tested value provided that a minimum ultimate factor of safety of 5 is maintained.

Load cells shall be calibrated immediately after each proof test.

Note: Hydra-Sets and Load Cells that will be used at a launch site, as part of a ELV launch, require NDI.

4.1.3.9 *Location:* Proof-testing of cranes or equipment shall be performed in a location which precludes possible JCI damage in the event of a failure. If crane or equipment proof-tests cannot be performed as required due to the presence of flight hardware, a Systems Safety Request for Waiver shall be submitted to the Systems Safety Office, in accordance with Paragraph 1.3.4 of this document.

4.1.4 Test and Servicing Equipment Proof and Validation

4.1.4.1 *Electronic GSE and Instrumentation:* Electronic GSE and test instrumentation shall be initially validated and/or calibrated before use and at predetermined intervals thereafter as specified by the Instrument Services group. EGSE components shall meet the intent of NEC (National Electrical Code) or tagged as UL, or equivalent. Significant interface cables should be megger tested to verify integrity of wiring/insulation.

4.1.4.1.1 Test Instrumentation: Electronic test instruments, either installed or portable, shall be calibrated prior to use, and shall have a calibration due date posted on the equipment.

4.1.4.1.2 Electronic GSE: A plan for periodic revalidation of all electronic GSE shall be established. This plan may include frequent self -test capabilities coupled with less frequent periodic revalidation.

4.1.4.1.3 Safe-to-Mate EGSE/Hardware Interface Test: Safe-to-Mate hardware/GSE electrical interface tests must have verification that both sides of the interface (end-to-end) are represented in a common or interface document. The document data may stem from the EGSE side, the Flight side or an Interface document, providing that both sides of the Safe-to-Mate are verified to the same description. A Safe-to-Mate interface test need only be done once, unless the equipment is modified or the configuration is changed (cables, etc). A Safe-to-Mate interface that is verified by separate EGSE and Flight documentation is not acceptable.

4.1.4.2 *Servicing GSE*:

4.1.4.2.1 Pressure Vessels Pressure: Vessels shall be periodically inspected, proof tested and appropriate NDI performed in accordance with the inspection and test requirements stipulated in JPL Policy “Pressure Vessels and Systems”. All ground based pressure vessels fall under the maintenance and inspection requirements governed by the JPL In-service Inspection Program referenced in JPL Policy “Pressure Vessels and Systems” and relegated by NASA Policy Document NPD 8710.3 “NASA Safety Policy for Pressure Vessels”.

Replacement or repair of the vessels shall be accomplished when determined necessary by the inspection or the corrosion rate determined from the fracture mechanics evaluation. Findings from the inspections or analyses may require hydrostatic testing before reuse of the vessel.

Safety precautions shall be taken when opening tanks which have contained toxic or otherwise hazardous fluids or gases.

4.1.4.2.2 Pressure Systems: Pressure systems shall be inspected periodically to determine current and projected maintenance requirements. The period chosen shall take into account the frequency of use, environment, stresses, and other special conditions. (See Section 4.3.1 for detailed requirements)

Appropriate safety precautions such as chemical aprons, gloves, face shields, breathing apparatus, etc. shall be taken when opening systems which contain or have contained toxic or otherwise hazardous fluids or gases.

4.1.5 Procedures

4.1.5.1 *Required Use:* The following types of operations shall be performed using approved and reviewed procedures:

(1) Operations involving JPL critical items.

(2) Support equipment validation or qualification tests.

(3) Hazardous operations.(*Note): Hazardous Operation. An operation is considered hazardous if it poses a risk for personnel, injury or death, or of damage or loss of JCI.*

4.1.5.2 *Marking of Cover:* Procedures shall be marked on the front cover with one of the following statements:

(**1) "THIS PROCEDURE CONTAINS HAZARDOUS OPERATIONS".**

(2) "THIS PROCEDURE DOES NOT CONTAIN HAZARDOUS OPERATIONS".

4.1.5.3 *Marking within the Procedure:* Where a hazardous operation is to be performed the appropriate page and steps shall be marked with the following statements:

(1) Prior to the start of any hazardous operation a warning note shall state **“THE FOLLOWING STEPS CONTAIN HAZARDOUS OPERATIONS”.**

(2) At the completion of a hazardous operation, immediately after the last step, a note shall state "**END OF HAZARDOUS OPERATIONS**".

(2) Each page of the procedure that contains hazardous steps shall be marked with an "H" in the right-hand upper corner.

4.1.5.3.4 Caution Notes: A caution note shall appear in the procedure immediately prior to a step which could be hazardous to equipment.

4.1.5.5 *Warning Notes*: A warning note shall appear in the procedure immediately prior to a step which could be hazardous to personnel.

4.1.5.6 *Hazardous Commands:* A hazardous command list or matrix shall be developed showing each major test configuration and identifying the specific commands which require special inhibits , warnings, or other precautions prior to issuance of the command. The method of control of the hazardous command shall be identified.

4.1.5.7 *Approval*: The determination of the appropriate level of approval shall be at least one level of supervision/management above the actual doing organization. The SSO recommends that the following guidelines be considered:

Criteria	Recommended Approval Level
No hardware impact or hazards involved	Engineer
Personnel or hardware hazards involved	Cognizant Engineer/PEM
or	Group Supervisor
Degradation or reduction of lifetime of hardware	Project/Task Manager

The System Safety Engineer assigned to the Project/Task shall review and approve all hazardous procedures that are Project/Task involved.

4.1.6 Certification of Fluids and Gases

Fluid or gas supplies, including pressurized gas cylinders, (such as 'K' cylinders), shall be validated prior to connection to JCI's. The certification shall be performed on the gas withdrawn from its container. In most cases, the vendor's certification shall not be sufficient verification to meet this requirement (see the following note).

The validation criteria shall be established by the cognizant organization. Supplies shall be revalidated each time the storage supply is changed or recharged (See Section 4.3.1.1).

Note: Vendors typically certify the gases that are used to charge cylinders and other portable containers, and not the gas that is in the container itself. Therefore, a contaminated container will not be detected by verification of the gas used to charge the container.

4.1.7 Damage or Discrepancy Reporting

Personnel involved in JCI activities shall immediately report any observed hardware damage or discrepancy to cognizant engineering or Quality Assurance personnel. Conditions such as overtorquing of , impacts to hardware, excessive test stimuli, out-of-tolerance environmental or contamination conditions, or any other questionable condition shall be identified and documented per Section 1.3.6. This action shall not be used as the basis for any punitive action . Individuals shall be encouraged to report discrepancies and should not fear punitive reprisal because of their reporting action.

4.2 TRANSPORTATION AND HANDLING

4.2.1 Applicability

The following requirements shall apply to the packaging, handling, transporting, and storing of JCI's.

4.2.2 General Handling

JCI's are often very delicate and very sensitive to physical, electrical, and environmental damage. Parts are more delicate than they appear and are therefore easily subject to damage.

Since personnel and hardware safety are strongly interrelated, safety for hardware is usually consistent with safety for personnel.

The following general requirements shall be followed for the handling of JCI's. Individual project documents should be reviewed since project requirements may be more stringent than those contained herein. Specific precautions are detailed in paragraphs covering specific types of equipment or systems.

The following general requirements shall be followed for the handling of JCI's. Individual project documents should be reviewed since project requirements may be more stringent than those contained herein. Specific precautions are detailed in paragraphs covering specific types of equipment or systems.

4.2.2.1 *Responsibility:* The handling and movement of delicate, critical, costly, or hazardous items shall be accomplished under the control of the cognizant hardware engineer or the ground operations engineer to ensure that safety of both personnel and hardware are fully maintained.

4.2.2.2 *Personnel Considerations:* (Refer to Section 4.10 for general personnel requirements.)

4.2.2.2.1 Buddy System: Two or more persons shall always be involved in the handling and movement of JCI's.

At least one of these persons shall be knowledgeable of, or directly associated with, the hardware equipment being moved.

At least one of these persons shall be tasked with observing for hazards during movement, opening doors, controlling pedestrian or vehicular traffic, etc.

Note: For practical and economic reasons, this requirement for the buddy system does not apply where flight hardware is small and light enough to be easily carried by one person (e.g., when transporting small flight items by plane or car).

4.2.2.2.2 Jewelry: Finger rings, wrist watches, and other items which could mar sensitive hardware surfaces shall not be worn in the vicinity of JCI's. Items which cannot be removed shall be covered with tape or other medium which will prevent hardware damage in the event of inadvertent contact with the flight hardware.

4.2.2.2.3 Pockets: When working over (above) JCI's, all items such as badges, pens, pencils, notebooks, and keys shall be removed from pockets.

4.2.2.2.4 Tethering: Eyeglasses, hard hats, tools, or any other items which could fall into or onto the JCI shall be removed or positively tethered.

4.2.2.2.5 Untrained Personnel: Untrained personnel involved in the handling or movement of a JCI shall be escorted by trained personnel with flight hardware certification.

Such personnel shall be specifically briefed with instructions and precautions appropriate to the specific hardware involved. The following points shall be considered:

(1) Where to touch and where not to touch.

(2) Acceptable tie-down points.

(3) How to lift, carry, and set down the specific hardware.

(4) Clearing all actions with the cognizant engineer before proceeding.

(5) Specific sensitivities of the hardware, such as:

(a) Vibration or other accelerations.

(b) Excessive light (sunlight).

(c) Excessive heat or high temperatures.

(d) Areas particularly sensitive to impact.

(e) Harmful contamination (such as dust, moisture, skin oils, solvent or chemical vapors).

(f) Mating or de-mating connectors without approval.

(g) ESD vulnerability.

4.2.2.2.6 Grounding: Personnel and equipment grounding requirements shall be observed during movement of ESD-vulnerable JCI's to prevent the accumulation of electrical charges which may lead to electrostatic discharge (ESD) and subsequent potential damage to the JCI. A fully fueled Spacecraft/transporter shall have a trailing ‘ground’ for transportation between intra-facility and/or transportation to the launch pad.

All EGSE shall have the rack equipment ground, between chassis and ground, verified. Also, between each pin of the AC connector and ground verified.

4.2.2.3 *Procedures and Instructions:* Specific, written instructions or procedures shall be issued for packaging, handling, shipping, and safeguarding JCI's. These instructions shall cover known contingencies , including:

(1) Periods when the equipment is not under the direct control of the furnishing technical cognizant organization. (When equipment is delivered to a Spacecraft Assembly secure and clean Hi-Bay area or other approved Facility, it is frequently considered to be in the possession of, and the responsibility of, the Flight Systems Section. However, this does not relieve the cognizant organization of ultimate responsibility for the safety of the hardware.)

(2) Periods when such equipment is to be transported, shipped, tested, stored, or used in areas over which the furnishing organization does not have complete control.

(3) Periods when such equipment is in a facility where a cognizant engineer is not in constant attendance.

It shall be the responsibility of the cog nizant technical Section Manager to verify that the generation of proper transportation and handling instructions or procedures is accomplished.

4.2.2.4 *Storage:* Whenever assembly, inspection, and test operations are not being performed on the JCI , it shall be kept in designated areas that will protect the equipment from damage due to adverse environment, accident or earthquake.

(1) To the maximum extent practicable, such equipment shall be stored within shipping containers or stored inside cabinets having doors that are kept closed and securely fastened.

(2) Storage areas shall be routinely patrolled by Security personnel and, whenever feasible, shall be limited access areas.

(3) Storage shelves shall have strong lips or rims fastened to the front edges to prevent items from "walking, rolling or being pushed off," especially during earthquakes.

(4) Stored equipment shall be plainly identified as a JCI, i.e.: Flight equipment or Project-critical GSE (refer to Section 3.7.5, Storage, Shipping, and Transportation Equipment).

4.2.2.5 *Falling Objects and Hidden Utilities*: Suitable overhead protective coverage shall be provided when assembly, inspection, and test operations are conducted in areas where overhead objects could fall on the JCI, especially during earthquakes. Attention should be paid to the location of hidden utilities, such as water lines, GN_2 or other gaseous lines and electrical wiring. Such utilities are rarely fail-safe.

4.2.2.6 *Work Surfaces:* The following requirements shall be observed for work surfaces to protect hardware during work activities and earthquakes:

(1) Assembly, inspection, or test benches shall have nonskid surfaces and, to the maximum extent practicable, shall have strong lips or rims to prevent personnel from accidentally brushing up against projecting hardware, causing possible damage or falling to the floor.

(2) Special holding fixtures shall be used to firmly attach equipment to the work surface for assembly, inspection, and test operations whenever such attachment is practicable.

(3) Work surfaces shall incorporate ESD protection as defined in Section 4.2.9, if the equipment, activity or the area requires such protection.

4.2.2.7 *Work Areas:* Work areas shall be kept free of extraneous material and equipment which could create congested or other working conditions that could be hazardous to the JCI.

4.2.2.8 *Lateral Stability:* Objects and cabinets/containers having narrow bases (height-to-base ratio >5:1) or which are likely to be unstable for other reasons shall be braced, anchored, or otherwise secured to prevent their fall during earthquakes or other inadvertent movement. In order for a free standing structure to be considered stable, the structure must resist turnover when 1/4 of its total weight (structure + contents) is applied horizontally through its center of gravity.

Note: Cabinets that contained hazardous chemicals and had a height-to-base ratio of <5:1 were toppled in the 1993 Northridge Earthquake.

4.2.2.9 *Tie-downs*: JCI's shall always be in a secured position to prevent unexpected tip-over, slippage, rolling, or falling.

4.2.2.10 *Tools:* Worn, damaged or uncalibrated tools shall not be used on JCI's.

4.2.2.11 *ESD*: JCI's shall be handled as ESD-sensitive equipment unless the hardware cognizant engineer has stated otherwise, in writing. Refer to Section 4.2.9 for ESD precautions.

4.2.2.12 *Handling Equipment:* The Cognizant Hardware Engineer shall verify that all handling equipment used for JCI's is:

(1) Operated by certified personnel.

> *Note: The Lead person for crane operations shall ensure that all personnel involved in the operation are made aware of every significant crane movement, especially changes in speed or direction.*

(2) Operating safely.

(3) Suitable for the task.

(4) Qualified for the task (inspected, proof-tested, certified, etc.).

(5) Used in a proper and safe manner.

(6) Clean and uncluttered, with no objects present that could roll or fall against an item.

4.2.3 Lifting Operations

4.2.3.1 *Cranes:* Cranes and hoists used at JPL are proofed and inspected to CAL-OSHA requirements. Cranes rated for over 3 tons require an annual inspection. Cranes rated at less than 3 tons are inspected every four years.

The following requirements for utilizing cranes and hoists for JCI's shall be observed:

4.2.3.1.1 Emergency Shut-off: The emergency shut-off power breaker or switch shall be manned at all times that the crane is energized and attached to a JCI. A communication path between the crane operator and the person attending the emergency shut-off device shall be established and verified prior to the initiation of the lifting operation.

4.2.3.1.2 Suspended Equipment: JCI's shall not be left suspended or hanging unattended on cranes or other lifting devices for extended periods of time. For the purposes of this requirement, the definition of "extended" is necessarily judgmental and shall be determined in the light of "reasonable and prudent" for a given situation. Overnight is an unacceptable period, assuming that overnight implies unattended.

Under no circumstances shall personnel be allowed under a suspended load without appropriate supports. In order to enter the area under a suspended load, stable supports shall first be positioned in such a manner that should the load fall, it would fall onto the supports which shall be of sufficient height and stability that the personnel under the load would not be injured.

Operations that cannot meet this requirement shall be analyzed and documented as specified in NASA Alternate Safety Standard for Suspended Load operations. This standard may be found in NSS/GO-1740.9 "Safety Standard for Lifting Devices and Equipment."

4.2.3.1.3 *Load Supports*: Under no circumstances shall personnel be allowed under a suspended load without appropriate supports. In order to enter the area under a suspended load, stable supports shall first be positioned in such a manner that should the load fall, it would fall onto the supports which shall be of sufficient height and stability that the personnel under the load would not be injured. Operations that cannot meet this requirement shall be analyzed and documented as specified in NASA Alternate Safety Standard.

4.2.3.1.4 Umbrellas, Overhead Lifting Devices, Including Cranes and Cherry Pickers: Shall include a protective shield, tray, or parasol or umbrella to protect the JCI from overhead debris or lubrication drips which may fall from the overhead apparatus. If use of such a device is impractical, the JCI shall be covered with material that meets JPL requirements for ESD control and contamination.

4.2.3.1.5 Restricted Motion: Movement of cranes and other lifting devices shall be restricted to a single direction of movement when within 1.5 meters (5 feet) of a JCI.

4.2.3.1.6 Side Loads: Side loads shall not be allowed on a crane, hook, or cable at any time with or without a load on the hook.

4.2.3.2 *Proof-Loading*: The proof-load status of the crane and all lifting equipment shall be verified to be current prior to the lifting operation (Refer to Sections 4.1.3.6, Cranes, Assembly, Handling, and, Shipping Equipment, and 4.1.3.8, Miscellaneous

Equipment).

4.2.3.3 *Hydra-Sets:* Manually controlled Hydra-Sets, or cranes with inching motors, shall be utilized when mating or de-mating sensitive hardware joints during lifting operations. The following requirements shall be observed when using Hydra-Sets. (Refer to Section 4.1.3.8.1 for proof test requirements.)

4.2.3.3.1 Pneumatically Controlled Hydra-Sets: Pneumatically controlled "Hydra-Sets" shall not be used for handling JCI's. When used in accordance with the manufacturer's instructions to control the load with the "LOAD REGULATOR," these devices are inherently unstable, are extremely difficult to control over very short distances or increments, are particularly hazardous when mating or de-mating overlapping joints, and have no stable "emergency stop" condition. Specific approval shall be obtained from the Systems Safety Office if sufficient safety can be demonstrated using alternate procedures and/or control console modifications.

In situations where pneumatically controlled Hydra-Sets are used, the following criteria shall be satisfied:

(1) A positive "hands-off" stable mode shall be demonstrated. The achievement of a "NULL" on a pressure regulator-type device is not satisfactory to meet this requirement.

(2) The addition or subtraction of mass to the hanging load shall not result in continuous un-commanded Hydra-Set motion.

(3) A positive piston travel indicator shall prominently display piston movement to the Hydra-Set operator.

(4) The Hydra-Set controls shall be operated in a manner that precludes the possibility of vertical oscillatory motions (yo-yoing) in the event of operator over control.

Compliance to these requirements shall be demonstrated and specific approval obtained from the Systems Safety Office for each lifting situation involving pneumatically controlled Hydra-Sets.

4.2.3.3.2 Load Measuring Device: When the neutral-mass lift point must be known during a mating or de-mating operation, a load-measuring device (load cell, etc.) shall be included in the lifting equipment. Situations requiring load measuring include:

(1) Overlapping joints such as Super*zip separation bands.

(2) Fork and blade joints or pinned joints.

4.2.3.3.3 Maximum JCI Load: The maximum JCI load that shall be permitted to be lifted by a Hydra-Set is limited to the de-rated value as determined in Section 4.1.3.8.1.

4.2.4 Movement of Hardware On-Site

"On site" is defined as movement or transportation between rooms or buildings but within facility or institution boundaries. Ref. Safety Practice 4-08-101 "JPL Critical Item On-Site Transport." It does not include movement over public highways. Movement is under the complete control of the cognizant hardware organization. In addition to the handling requirements of Section 4.2.2, the following requirements shall be observed during the movement of assemblies, subsystems, and systems.

4.2.4.1 *Elevators:* Elevators shall be utilized in preference to stairways during hardware movement to minimize the potential for stumbling.

4.2.4.2 *Containers:* Qualified containers or fixtures shall be utilized for the movement of JCI's (refer to Section 3.4.5 for design requirements).

4.2.4.3 *Responsibility:* The Cognizant Engineer or Project Element Manager shall be responsible for the safety of the hardware at all times. Movements of JCI's shall be made under the constant observation and control of the cognizant engineer, or his designee, under his written instructions.

4.2.4.4 *Duplicate Hardware:* Duplicate or backup hardware shall be moved such that no single incident causes loss of or damage to both the flight and the spare or backup hardware.

4.2.4.5 *Attendance:* A JCI shall not be left unattended at any time during its movement from one secure area to another. Items in intermediate stages of transport shall be protected with covers, barricades, and/or roped -off areas as necessary to protect the flight hardware from passersby and spectators.

4.2.4.6 *Traffic*: Hardware shall be moved when vehicular and pedestrian traffic is at a minimum. Major moves that will impact vehicular movement shall be coordinated with the Security department.

4.2.4.7 *Convoys:* The following requirements shall be observed when moving JCI's on-site:

(1) Convoy leading and following escort vehicles shall be equipped with flashing red or yellow warning lights. The lead vehicle shall be equipped with signs on the front and sides identifying the convoy as a JCI transport convoy and indicating that interruption or breaching of the convoy is not allowed. The trailing vehicle shall have a similar sign attached to the rear of the vehicle that prevents passing.

(2) Schedules and routes for major movements shall be established in advance and communicated to both the Security and Transportation departments.

(3) The convoy shall have the right of way over ALL pedestrian and vehicular traffic. Vehicular traffic facing the convoy and on the convoy route shall pull over to the right, stop, and wait for the complete passage of the convoy before proceeding. Vehicular traffic following the convoy shall not attempt to pass. Pedestrians in the immediate vicinity of the convoy shall not be allowed to enter the convoy roadway during the passage of the convoy.

(4) Emergency vehicles responding to an emergency shall have the right of way over the convoy; however, mutual respect of each other's mission shall prevail. The convoy shall move over and/or stop as quickly as possible to permit emergency vehicle safe passage. Because the emergency vehicles may not be familiar with the criticality of the hardware in the convoy, every effort shall be taken by the convoy participants to expedite the safe passage of the emergency vehicles.

(5) Small flight hardware subsystems and instruments not requiring a full convoy shall be afforded ample protection in the same spirit as above. The PEM responsible for furnishing the equipment shall make the decision on whether or not a convoy is required. If in doubt, the Systems Safety Office shall be consulted.

4.2.4.8 *Fork Lifts*: The operations and proof testing of Fork Lifts shall be in compliance with CAL OSHA. In addition, this equipment shall be subject to the following requirements when used at JPL:

4.2.4.8.1 Overturning Moment Of The Fork Lift: For normal fork lift movements greater than 5 MPH, the moment generated by the payload shall not exceed 50% of the moment necessary to overturn the fork lift. The moment arm is the distance between the front wheel axle and the center of gravity of the load. Below 5 MPH, for limited local movement (truck off-load), a maximum moment of 75% is allowed.

4.2.4.8.2 Fork Lift Speed: A payload (JCI) shall be transported no faster than approximate walking speed, and shall be secured to the Fork Lift in a manner that prevents movement of, and damage to, the payload.

4.2.4.9 *Safety Review:* Transportation of JCI hardware at the subsystem level or above shall be preceded by a Transportation Safety Survey as detailed in Section 4.9.3.

4.2.5 Transportation Between Sites

"Between sites" is defined as movement or transportation outside facility or institution boundaries requiring movement over public roads or highways, or other means not under the total control of the hardware cognizant organization.

4.2.5.1. *Transportation Security*: When flight hardware is transported from one destination to another, whether by land, sea or air, security cognizance and protocol must be closely followed. Security requirements for all methods of transportation are at a high level, particularly when certain events lead to more sensitivity. Flight (JCI) equipment shall be enclosed in special containers and/or designated storage areas to protect the equipment against physical, environmental and static charge damage while in storage or during transportation. Procedures shall be provided by the responsible organization to cover the handling, storage, packaging, preservation and delivery of the JCI to insure its integrity, functionality and safe delivery upon arrival at a given destination. When transporting sensitive hardware by US Air Carriers the instructions in JPL SPI 4-13-16 "Airport X-Ray or Visual Inspection of Scientific Equipment" should be followed. For up-to-date transportation restrictions, guidance or information, contact with the JPL Contract Management Office (Ext. 4-4220) should be made prior to making any travel arrangements. A JPL section letter addressed to Airport Security and approved by the JPL Section Manager, JPL Prime Contract Compliance Section and the NASA/JPL Security Office must accompany the hardware for exemption from X-Ray and/or visual examination. This letter should include a description of the hardware sufficient to satisfy airport security. A Certificate of Safety (JPL form 2451) shall be approved and accompany any hand carried item unless it is hardware that is pyrotechnic or contains explosives, propellants, radioactive material or lithium batteries.

4.2.5.2 *Environmental Loads:* The shipping and transportation induced environment at the JCI /fixture interface, or at the center of gravity of the assembly or its subsystem, shall at no time exceed a defined fraction of the allowable design load. Transient or peak loads which may exceed a total of 2g (1+1g) on the GSE fixtures shall be specifically considered in determining the GSE proof load requirements defined in Section 3.7.5.

The cumulative fatigue level of the JCI and its transporter experienced during shipping and transportation shall not exceed the predetermined values. These values are a function of the structural design of the JCI and its transporter and shall be determined by the Cognizant Structural Engineer. Particular attention shall be given to assessing the coupling of the transportation system and the JCI natural frequencies.

4.2.5.3 *Container Qualification:* The containers used for the transportation of flight equipment shall be designed, qualified, and identified in accordance with the requirements of Section 3.4.5.

4.2.5.4 *Separation of JCI & Non-JCI Units:* Non JCI shall not be shipped in the same container as the JCI unless approved by the PEM and/or Project.

JCI's may be shipped in groups within a single qualified container if properly packed and if loss of the container would not seriously impact the Project, cost or schedule.

4.2.5.5 *Separation of JCI Hardware:* JCI hardware shipments shall be separated and divided such that the complete loss of a shipment shall not cause the loss of a program. This requirement should be interpreted as follows:

(1) Primary and spare hardware should be shipped separately.

(2) If a full complement of spares does not exist, then prime and redundant elements of the flight complement of hardware shall be shipped separately.

Note: This requirement does not apply to the shipment of a single (one and only) system or subsystem. In these cases, the Project Office has already accepted the risk that a single catastrophe could cause the loss of the mission.

4.2.5.6 *Evaluation of Environments:* Containers and transportation equipment used to ship large assemblies, subsystems, or systems shall be subjected to evaluation test runs in the air or on the ground to evaluate and verify the acceptability of the actual magnetic, shock and vibration environments. The test should utilize a structurally representative model of the hardware to be shipped. If not available, a sufficiently sensitive mass model having the proper mass and Center of Gravity characteristics may be substituted, if the appropriate Dynamics Engineers concur as to the acceptable level of simulation.

(1) The hardware model shall be sufficiently instrumented with strain gauges and accelerometers to define the loads in all critical areas.

(2) Acceleration measurements shall be made on the floor of the transporter to sufficiently describe the motion of the floor. Triaxial accelerometer measurements on the floor are required at each of the mounting locations.

(3) During the test run, the output of all strain and accelerometer measurements shall be continuously recorded simultaneously on magnetic tape or other suitable permanent recording equipment. Data processing shall consist of, but not necessarily be limited to, producing acceleration and strain/time traces, shock spectra, and power spectral density plots of recorded data selected by the cognizant structural engineer. That person shall decide on the acceptability of the transporter tested.

(4) Magnetic and electromagnetic (RF) fields associated with the transportation system shall be considered and if deemed appropriate they shall be measured and verified to be acceptable to the Environmental Requirements Engineer and the Cognizant Hardware Engineer.

4.2.5.7 *Highway Movements:* The following requirements shall be observed when moving spacecraft or large JCI assemblies over the highway:

(1) The truck or highway van to be used shall be visually inspected for defects such as suspension system structure and mechanism,

misalignment, tire wear, tie-down fixtures, etc. This inspection shall be performed prior to loading the JCI, and daily while en-route.

(2) Temperature/Humidity control equipment shall be redundant and proved to be in working condition within the range specified for the JCI Temperature/humidity levels within the cargo area shall be continuously recorded and monitored in real time.

(3) Once qualified, the truck or highway van shall not be used for any other activities prior to transporting the flight hardware.

(4) Triaxial accelerometers shall be installed on the van floor at each of the JCI mounting locations exactly as was previously done during evaluation and qualification.

(5) Outputs of all accelerometers shall be continuously recorded on magnetic tape or other permanent recording equipment throughout the trip.

(6) A warning system shall warn the driver when acceleration levels predetermined by the environmental requirements engineer are exceeded.

(7) If the warning system is triggered or a high-level acceleration environment is suspected, the van shall be stopped as soon as it is safe to do so and the cause investigated.

(8) Personnel familiar with all phases of the instrumentation and data recording system shall accompany the van.

(9) The speed of the truck shall never exceed legal speed limits.

4.2.5.8 *Aircraft Movements:* All practicable means shall be employed to evaluate the air transportation environment. Actual tests using flight model simulators may be impractical due to equipment availability and cost. An analytical evaluation may be made if sufficient aircraft dynamic characteristics are accurately known.

4.2.5.9 *Safety Review:* Transportation of JCI hardware at the subsystem level or above shall be preceded by a Transportation Safety Survey as detailed in Section 4.9.3.

4.2.6 Pressure Vessels

The following precautions shall be observed when handling flight pressure vessels containing greater than one-third of their man-rated pressure:

(1) Tank covers or other protective devices shall be employed to the maximum extent practicable.

(2) Handling shall be restricted to the minimum amount necessary.

(3) Extreme caution shall be observed.

(4) Excessive movement of the pressure vessel shall be avoided.

(5) Particular care shall be taken to verify that the solvents or other fluids used for external "casual" cleaning of pressure vessels are approved by the Cognizant Pressure Vessel Engineer. For example, isopropyl alcohol or Hydrofluorocarbons (HFCs) must not be used for cleaning titanium (6Al-4V) when the tank is pressurized to/or greater than one-third maximum allowable working pressure.

(6) If personnel are required in the hazardous area (i.e. not protected by a fragment barrier) the number of persons present shall be minimized but shall not be less than two (buddy system).

Pressure systems requirements are contained in Section 4.3.

4.2.7 Solar Panels

Due to the very low mass to area ratio, solar panels are extremely fragile and therefore require special handling precautions.

4.2.7.1 Personnel*:* Due to the extremely fragile nature of solar panels, all personnel involved in handling them shall be specifically trained and approved for handling solar panels.

4.2.7.2 *Storage*:*.* Solar panels shall be stored in protective covers and handling frames in approved storage facilities except when in use.

4.2.7.3 *Installation and Removal*: Solar panels shall be covered or rotated away from bright light sources when making or breaking electrical connections to the spacecraft. The panels are capable of producing several amperes of current when exposed to bright light.

4.2.8 Batteries

Batteries contain compounds that can be hazardous to personnel and hardware if they should escape the confines of the sealed cells. In addition, batteries have high current capacities when connected across low impedance's. For instance, Nickel Hydrogen batteries are capable of delivering high pressures during charging operations, and must be considered to be pressure vessels. Additionally, for Nickel Hydrogen batteries, there is the potential for Hydrogen gas leakage from the battery pressure vessel and the potential for an explosive mixture of hydrogen and oxygen in the cells. The following precautions shall be observed when handling JCI system batteries:

4.2.8.1 *Containers:* Battery cases shall meet the requirements of MIL-STD-1522.

4.2.8.1.2 System Test Batteries: Workhorse (non-primary) batteries installed on the flight system for test purposes shall have a redundant container or barrier to prevent accidental escape of hazardous compounds.

4.2.8.1.3 Orientation for Charging: Unless hermetically sealed, batteries shall be in an upright position during charging to permit the escape of generated gases. This would normally be the launch orientation for flight batteries and systems.

4.2.8.1.4 Installation Verification: The load side of the battery connector shall be verified for the absence of shorts prior to the connection of any battery.

4.2.8.1.5 Ground Current Leakage: The battery shall be removed from the JCI system immediately if leakage current to system ground is detected.

4.2.8.1.6 Storage and Test: Batteries shall be tested and/or stored in a dedicated facility or room separate from the JCI system area. Such facilities shall be designated as "HAZARDOUS."

4.2.8.1.7 Insulation Verification: Prior to activation of a wet cell battery, the battery insulation shall be verified by a megger test.

4.2.8.1.8 Charging Procedures: Battery chargers and batteries shall be placarded with instructions for both normal charging and for recovery after power outage.

4.2.8.1.9 Configuration Verification: Battery test configurations shall be verified by Quality Assurance prior to application of power.

4.2.8.1.10 Pre-installation Load Test: Batteries shall be tested under full operational load prior to installation and use with JCI hardware.

4.2.8.1.11 Waiting Period: A waiting period of 48 hours following battery discharge shall be observed prior to handling, securing and sealing a discharged battery in a shipping container.

4.2.8.1.12 Storage Temperature: The maximum allowable storage temperature for the specific battery shall not be exceeded. Nickel Hydrogen batteries shall not exceed 30 degrees C or fall below –25 degrees C, at any time.

4.2.8.2 *High Energy Density Batteries*:

4.2.8.2.1 Lithium Batteries:

There are two basic types of Lithium Batteries:

(1) Primary, non-chargeable.

(2) Rechargeable - liquid electrical
- polymer electrical.

In all respects Lithium Batteries are hazardous and can fail with a violent release of energy (emitting toxic/corrosive materials) if exposed to environmental conditions beyond their design limitations.

Users should develop procedures to avoid:

(1) Charging/reverse currents to primary batteries.

(2) Excessive charging of secondary batteries.

(3) Excessive shock/g loads caused by physical abuse.

(4) Shorting/improper electrical loads resulting in excessive current flow and elevated temperatures.

(5) Puncture or rupture of a battery cell/case.

Packaging/shipping of Lithium Batteries must be done professionally, in accordance with shipping regulations, and with the approval from the JPL Electric Power Section (342). All Lithium Batteries above 2Ah or AA size must have DOT approval before transportation.

4.2.9 Electrostatic Discharge

Much of the spacecraft electronic circuitry is vulnerable to damage from electrostatic discharges (ESD).

The presence of static electricity at levels sufficient to destroy or cause latent damage to sensitive components cannot be detected or determined by human senses. Proper ESD prevention practices shall be employed. (Ref. D-1348).

The following partial list of requirements shall be followed to reduce static charges to an absolute minimum to avoid damage to sensitive spacecraft components. A complete listing of requirements can be found in JPL Standard D-1348, "JPL Standard for Electrostatic Discharge (ESD) Control".

4.2.9.1 *ESD Control Survey and Approvals:* The ESD Control Engineer shall approve all garments, wrist straps, packaging materials, antistatic agents, etc, that will be used in ESD-controlled areas. (See Appendix B of JPL D-1348.) All ESD control materials and/or equipment, used at JPL, shall be obtained from the JPL approved ESD Control Materials List. A Certificate of Compliance will be issued upon successful completion of the ESD Control Survey process.

4.2.9.2 *ESD Survey*: An electrostatic discharge control plan shall be generated for each project. Requirements for documentation, control, prevention, and protection for each Flight Project shall conform to the JPL Standard D-1348, "JPL Standard for Electrostatic Discharge (ESD) Control".

4.2.9.3 *Operations:* The following are typical operations where ESD control procedures shall be required for ESD-sensitive equipment:

(1) Inspection of ESD-sensitive items at any level -- piece-part, assembly, black box, subsystem, or system (spacecraft).

(2) Handling in any way except when the ESD-vulnerable items are enclosed in packaging that renders them immune to external ESD damage.

(3) Packing or unpacking operations.

(4) Assembly.

(5) Test.

(6) Troubleshooting.

(7) Any other operations in that hardware movement or personnel are involved.

The relative humidity shall never be less than 30% anytime work is performed on ESD sensitive items.

4.2.9.4 *Metallic Structures*: Metallic structures that can come in contact with the hardware shall be grounded through a resistance of 2 megohms or less. This requirement includes (but is not limited to) test stands, clean benches, equipment around work areas, storage shelves, and cabinets.

4.2.9.5 *Furniture:* Furniture surfaces capable of generating an electrostatic charge shall have those surfaces covered with an approved antistatic material or be treated with an approved antistatic treatment (topical antistat). The latter is less desirable because of the ease with which a topical antistat can be worn off and could prove to be a contaminant. Surface charges shall not exceed +200V during natural use.

4.2.9.6 *Garments:* Approved antistatic garments for use in circumstances where ESD protection is required shall be provided by the facility. These garments shall be approved by the JPL ESD Control Engineer as ESD-safe before being used in the vicinity of ESD-sensitive equipment. (Ref. D-1348).

4.2.9.6.1 Configuration: Personnel working on or in the vicinity of ESD-sensitive hardware shall wear permanently noncharge-generating (STERN & STERN CHEM-STAT 909 or equivalent) outer garments capable of protecting the hardware from static charges on personal clothing, and other hazards as applicable. The garment shall be long-sleeved and tight-fitting at the wrists, and worn fully buttoned or zippered. Use of a permanently noncharge-generating, calf-length smock shall be permitted where cleanliness does not require a one-piece coverall, or "bunny suit."

The suit shall be worn in the fully closed configuration so that all clothing under the suit is covered to prevent the exposure of static charges. Furthermore, the suit minimizes any electric fields generated by regular clothing worn underneath.

4.2.9.6.2 Material: The required garment shall be made of continuous filament polyester with a conductive fiber, such as metallic or carbon impregnated material, woven into the garment at approximately 1 cm (0.4 inch) spacing.

Currently acceptable materials are CHEM-STAT 909 and Cubic 10. Materials proven to be equivalent may also be used if approved as specified in Section 4.2.9.1. Other properties that shall be evaluated in establishing the overall acceptability or equivalence include particulate sloughing and volatile condensible material outgassing.

Note: Bulk ESD controlling materials may have questionable quality control. Acceptable material, in the past, was produced by “third world” countries and, as such, was manufactured in a non-regulated environment, producing inconsistent results. Currently, Burlington Mills (USA) is producing the CHEM-STAT line of ESD materials and these (particularly, CHEM-STAT 909) are candidates for acceptable ESD control garments.

4.2.9.6.3 Laundering: Specific care should be given as to the choice of a launderer for ESD control garments. Consistency and honesty of the launderer are paramount. Spot checking for ESD measurements should be performed on each batch of ESD control garments sent out for cleaning. A tertiary amine should be included in the final rinse of all ESD control garments.

4.2.9.6.4 Material for Temporary Garments: A temporary substitute material is Tyvek, spun high density polyethylene (polyolefin), commonly but erroneously referred to as ‘paper.’ This material may be worn only as new stock and shall not be laundered because the material loses its nonchargeable characteristic.

The temporary suit material is also acceptable for visitors or peripheral workers.

Each temporary suit shall be verified to be ESD acceptable prior to initial use if ESD-sensitive parts or equipment will be handled by the wearer. This is required because occasionally individual portions of garments (arms, legs, or body) have been found to generate charges.

4.2.9.7 *Personnel Grounding*: Persons handling or touching ESD vulnerable hardware shall be connected to ground through a maximum of ten megohms resistance. The actual resistance used is nominally 1 megohm and is dependent on the grounding scheme used.

Wrist straps and other devices shall be verified for continuity each day prior use.

4.2.9.8 *Equipment Grounding:* Items being connected to the ESD-vulnerable hardware shall be electrically connected to a ground common to the hardware ground through a maximum of two megohms resistance prior to connection to the sensitive hardware. If this is not possible, the items shall be verified to have less than one volt peak ac or dc charge build-up prior to connection.

4.2.9.9 *Clean Tents or Equipment Covers:* The physical properties of the tent material shall preclude the accumulation of a static charge due to the triboelectric effect of the air movement in the tent, or during the separation of materials.

The material shall be sufficiently conductive and electrically connected to the system ground so that any generated charge will not be allowed to build up.

4.2.9.10 *Plastic* Items*:* Plastic items within the ESD-controlled area shall be made of nonstatic material, or have been treated with an approved antistatic agent. This requirement applies specifically to plastic bags, boxes, tapes, and folders, and to any other plastic items which may be transported inside the controlled area. Topical anti-stats are less desirable because of their tendency to wear off during handling and because of contamination to sensitive JCIs (such as optical surfaces).

4.2.9.11 *Fluid Lines:* Fluid lines on or connected to the spacecraft shall be grounded. Fluids flowing through hoses made of nonconducting material can produce an electrostatic charge on the inside of the hose or line due to the triboelectric effect.

When hoses of nonconducting materials must be used, an intermesh lining or imbedded wires in the inside wall connected to conductive fittings at both ends should be considered.

When fluid incompatibilities prevent use of the above suggested static charge bleed-off methods, an analysis shall be conducted to verify that no damage to the spacecraft can occur.

4.2.9.12 *Static Discharge Lines:* Static grounding lines shall be attached from the reference ground plane to the spacecraft or other large equipment being moved.

The static grounding line shall be attached to the spacecraft as well as the object used to move it, such as the crane hook, hoist, tug, etc., and to the reference ground plane. Continuity of the grounding lines shall be verified.

4.2.9.13 *Cabling:* Open, unterminated cables shall be discharged just prior to connection to ESD-sensitive hardware. Handling, flexing, or rubbing unterminated cables can charge the conductors.

The cables can be discharged by first connecting to the support equipment, by shorting to ground, or by the use of an approved, balanced ionized air blower .

4.2.9.14 *Discharging of Charged Items*:. When ESD-sensitive items or equipment are found to contain a charge, one of the following steps, in order of preference, shall be taken:

(1) Stop all operations or activities in the vicinity and allow the item to naturally discharge to ground potential.

(2) Blow ionized air over the item or area to slowly dissipate the charge. The air ionizer must be balanced.

(3) Carefully connect a static discharge line with approximately 10^8 ohms series resistivity. Extreme care shall be exercised to avoid rapid discharge through the human body or other objects.

In all cases, a slower discharge aff ords greater safety for the equipment.

4.2.9.15 *Blowing Dry Gas:* Blowing gas over ESD-vulnerable hardware, even at a pressure of 206.8 kPa (30 psig) or less could generate hazardous levels of static charges.

Clean air at a relative humidity of 30% or more and a pressure of 206.8 kPa (30 psig) or less is usually safe. However, the ESD Control engineer should be contacted to review the operations prior to commencement of such an activity.

4.2.10 *Ordnance and Pyrotechnic Devices*:

4.2.10.1 Included Items: The term "ordnance" includes, but is not limited to, solid propellant motors, ignitors, initiators, explosives, pyrotechnics, and electroexplosive devices.

4.2.10.2 *Packaging:* Ordnance devices shall be packaged in and protected by a conductive material that complies with all NASA, IAADA, State and DOT regulations.

4.2.10.3 *Transportation:* Shipments of ordnance devices shall comply with municipal and state regulations. The following agencies control shipments as follows:

(1)	ICC/DOT/IATA	Shipments by common carrier.
(2)	U.S. Air Force	Shipments by military aircraft.
(3)	U.S. Coast Guard	Shipments by water.

4.2.10.4 *Identification:* Ordnance or ordnance simulators shall be identified per Section 2.4.6.

4.2.10.5 *Shielding Caps:* Electroexplosive devices shall have shielding caps installed at all times that the device is not cabled to either flight or test equipment. See Section 2.4.4.4.1 for shielding cap design requirements.

4.2.10.6 *Personnel Protective Equipment:* Personnel involved with the inspection, handling, or test of ordnance shall utilize protective equipment as follows.

4.2.10.6.1 Flame-Retardant Clothing: Flame-retardant and static-free clothing shall be worn by all persons involved with or in the vicinity of solid propellant or electroexplosive device operations. Certification of the flame-retardant status of the garment shall be visible on each garment.

4.2.10.6.2 Personnel Grounding: Wrist-straps, or heel-stats in conjunction with conductive flooring or floor mats, shall be utilized by all personnel handling ordnance.

To prevent any charging of the mat in the event of a lightning strike to the building, mats installed specifically for ordnance shall be disconnected from the building when a lightning storm is within 8 kilometers (5 miles). Mats connected to the spacecraft ground (separate from the building ground) may remain connected.

Personnel grounding devices shall be electrically verified daily during all hazardous operations (see also Section 4.2.10.15).

4.2.10.6.3 Face Protection: Face shields or approved impact safety glasses (SURE-GARR, F9948M, American Optical Co., or equivalent) shall be worn by all personnel handling and installing or testing ordnance.

4.2.10.7 *Handling:* The following requirements shall be observed when handling and installing ordnance. RF silence shall be observed throughout all ordnance handling and installations operations. The handling of ordnance shall be performed by specifically authorized personnel.

4.2.10.7.1 Supervision: Handling operations (inspection, test, assembly, installation, etc.) shall be performed under the direct supervision of a competent person who thoroughly understands the ordnance hazards involved.

4.2.10.7.2 Handling Care: The importance of extreme care shall be impressed on all personnel who handle ordnance.

4.2.10.7.3 Personnel Quantity: At least two persons shall be present in the area for any ordnance handling activity. The maximum number shall be established, as appropriate for the specific activity.

4.2.10.7.4 Assembly Areas: Assembly, inspection, and test of ordnance items shall be performed in specially designed facilities.

4.2.10.7.5 Personnel Familiarization: Persons in the vicinity of ordnance operations shall be completely familiar with the appropriate emergency procedures and standard safety precautions, or shall be escorted at all times by a properly qualified person.

4.2.10.7.6 Nonstandard Ordnance Devices: Personnel shall not receive, handle, ship, store, or install any ordnance item (see Section 4.2.10.1) that does not meet the requirements for RF radiation, static electrical discharge, and spurious signal hazards.

4.2.10.7.7 Nonconducting Materials: Static generating, nonconductive materials, such as plastic film or synthetic fiber cloth, shall not be permitted near ordnance.

4.2.10.8 *Storage:* Ordnance shall be stored as Class 1.1, 1.3 or 1.4 explosives. The following general requirements shall be implemented:

4.2.10.8.1 Magazines: Storage magazines shall be designed for the storage of ordnance and shall meet the quantity/distance requirements of DOD 4145.26.

Each stored stack within the magazine shall provide thorough ventilation with adequate aisles between items so that the items may be inspected.

Ordnance items shall not be stored in operating buildings in quantities greater than the minimum required for the specific individual operation.

4.2.10.8.2 Containers: Ordnance items, including solid propellant motors, ignitors, and electroexplosive devices, shall be stored in approved containers.

Items may be held in ready storage on proper trailers or dollies, or in special magazines, in accordance with AMC-R 385-100 when specifically approved.

4.2.10.8.3 Orientation: Items that can become self-propelled shall be given storage priority in facilities that provide protection from inadvertent ignition.

Such items shall be stored nose-down whenever possible; otherwise, the items shall be oriented to present the minimum hazard in the event of inadvertent ignition.

4.2.10.8.4 Compatibility: Only compatible solid propellant items shall be stored together. (Solid propellants are compatible if two or more of these items stored together are no more hazardous than the comparable quantity of either of the items alone.)

4.2.10.9 Inspection of Ordnance Areas: Facilities and areas where ordnance (solid rocket motors and electroexplosive devices, etc.) is handled shall be inspected by the cognizant safety personnel.

Permanent records shall be kept of each facility inspection. All discrepancies shall be noted and reported in writing to the cognizant facility office for correction.

Inspections shall verify, but not be limited to, the following:

(1) All locations containing ordnance conform to the quantity/distance criteria specified in DOD 4145.26.

(2) The area is secure against unauthorized personnel.

(3) The area is protected against fire.

(4) Fire breaks are free from rubbish and combustibles.

(5) Magazines are well constructed, in good condition, and suitable for the storage of ordnance.

(6) Lightning air terminals (arresters) and grounding wires are in proper locations and good condition.

(7) Earth-covered magazines have proper earth coverage.

(8) Barricades are filled, and are high, wide, and strong enough to be effective.

(9) Water drainage is adequate.

(10) Proper fire symbols are conspicuously displayed at all storage locations (e.g., quantity and type of explosives, quantity limitations, etc.).

4.2.10.10 *Ordnance Assembly Area Precautions:* The following precautions shall be observed in addition to precautions identified in the specific operating instructions for the facility or operation:

(1) Ordnance operations shall not be conducted while other operations are being conducted in the same room, or in the same facility if a failure could affect the personnel involved in the other activity.

(2) Solid propellant motor assembly operations shall be conducted in controlled areas specifically designed and approved for this purpose.

(3) Personnel involved in ordnance handling operations shall be grounded.

(4) Static-producing materials shall be removed from the area.

(5) Personnel not directly involved in the ordnance operation shall be cleared from the area. Facility personnel limits shall be established, posted, and observed.

(6) Adequate fire protection shall be verified operational and ready for immediate activation.

(7) Electrical and electronic equipment shall be explosion-proof.

(8) Ignitor circuits shall have a shorting device.

(9) Operations shall be terminated and personnel evacuated from the area if an electrical storm approaches within 8 kilometers (5 miles).

(10) Flash photography shall not be permitted unless specifically approved by all safety offices involved in the operation (facility and spacecraft).

(11) Facility exits shall be placarded, and be clear and unimpeded.

(12) Smoking and flame-producing devices shall be prohibited from the controlled area.

(13) Heat-producing devices shall be prohibited from the controlled area unless specifically required. When used, a special permit shall be obtained from the safety offices involved, and the use shall be controlled by a written procedure and supervised by qualified personnel.

(14) Personnel protective clothing and equipment shall be worn by all personnel involved in the operation.

(15) Warning systems shall be verified operational.

(16) The Plant Security and Fire Department shall be notified of operations involving ordnance.

(17) Flammable solvents shall not be used in the ordnance area without specific authorization from the safety offices involved.

(18) Preparations shall be completed prior to the arrival of the ordnance into the assembly area.

(19) Lights (including flashlights) used in controlled areas shall be rated as explosion proof by the U.S. Bureau of Mines, or equivalent recognized testing agency.

(20) RF silence during all handling and installation operations of ordnance RF silence must be observed. Electromagnetic (RF) frequencies, emanating from sources such as antennas or microwave dishes, may jeopardize the integrity of ordnance items and cause critical or catastrophic hazards to occur. It is essential that ordnance facilities be assessed for, and be located remote from, RF interference.

4.2.10.11 *Fire:* The following preparations and practices shall be followed for fire fighting in ordnance controlled areas.

4.2.10.11.1 Fire Extinguishers: A minimum of two fire extinguishers shall be available for immediate use within the controlled area.

WARNING:

Halon extinguishers shall not be used directly on ordnance fires because the high combustion temperatures can cause the generation of Phosgene gas ($COCl_2$).

4.2.10.11.2 Fire Reporting: Fires shall be reported promptly to the facility fire department. Reporting shall take precedence over local fighting of fires, unless it is absolutely clear that the fire can be extinguished quickly and promptly using the hand extinguishers.

4.2.10.11.3 Fire Fighting: Hand-held fire extinguishers shall be promptly used by personnel in the immediate vicinity of a fire only until ordnance is about to be ignited or consumed (see Section 4.10.5).

In all instances, personnel safety shall take precedence over facility or hardware safety. No attempt to use hand-held extinguishers should be made if such action appears to compromise personnel safety.

4.2.10.12 *Electroexplosive Device Connection:* Stray voltage checks shall be made before installing electroexplosive devices into their receptacles.

Stray voltage checks shall be made on both sides of the interface before mating electrical connectors to electroexplosive devices, or the cable harnesses to the device firing circuits.

If stray voltages are present, all work shall stop until the source of the stray voltages has been determined and the voltage removed.

4.2.10.13 *Electronic Equipment:* Electronic equipment associated with the spacecraft and powered by the facility supply shall not be used in checkout during the pyrotechnic installation.

4.2.10.14 *Procedures:* Inspection, assembly, test, and installation activities or operations shall be performed using approved, released procedures. These procedures shall include emergency and contingency procedures, as well as standard operating procedures for the specific facility or area in which the work is taking place.

4.2.10.15 *Grounding and ESD:* Electrostatic discharge shall be controlled by dissipating the charges to ground as fast as they are generated.

Category A ordnance devices, such as solid propellant motors and ignitors, and their attached handling fixtures shall be grounded at all times. Periodic verifications shall be conducted to ensure that no surface charges exceed ±200v. If charges greater than ±200 volts are discovered, all work shall be terminated immediately until the charge is dissipated, and the cause is determined and corrected.

Materials used within controlled areas, or near any ordnance devices shall be electrically conductive or statically disipative (see also Section 4.2.10.6.2).

4.2.10.16 *Records Review:* Transportation, storage, and handling records shall be reviewed to determine if environmental conditions (thermal, shock, humidity, vibration) could have degraded the solid propellant motors or other ordnance devices (see Section 2.5.2 for inspection requirements).

4.3 PRESSURE SYSTEMS

4.3.1 General

This section defines the requirements for the utilization of pressure systems containing both hazardous and nonhazardous fluids. The design requirements for flight and GSE pressure systems are contained in Sections 2.7 and 3.9, respectively.

All Composite Overwrapped Pressure Vessel (COPV) shall have a protective cover. The cover shall be such any impact damage is minimized. Stress analysis of the cover shall be required.

4.3.1.1 *Validation:* Gaseous or liquid systems shall be validated prior to attachment to certified GSE or flight hardware. The output of the GSE shall be revalidated each time the source or supply is changed or refilled unless the source or supply is certified (see Section 4.1.6).

4.3.1.2 *Transportation Pressure:* To reduce hazards to personnel and JCI's, pressure systems shall be transported at a reduced pressure (±one-fourth MAWP) or at full pressure if approved by DOT and SSO. This reduction in pressure is not required for the final preparation for flight (see also Section 4.2.6). DOT-rated and ASME-coded pressure vessels may be transported fully pressurized. All pressure vessels may be subject to additional limitations when transported and handled at launch complexes and other government facilities. The launch agency safety requirements documents shall be consulted in order to establish acceptable transportation conditions.

4.3.1.3 *Remote Pressurization:* Non essential Personnel shall be evacuated from the area and the system pressurized remotely or personnel locate behind a blast shield for the first pressurization after exposure to significant transportation or test environments, and each time the previous remote pressurization levels are exceeded. The pressure shall be held for 5 minutes prior to personnel working around the pressurized vessel.

The remote pressurization shall be conducted as remote as practicable from the

JCI hardware.

Personnel shall be evacuated from the area any time the Maximum Allowable Working Pressure is exceeded, e.g., proof-test s.

4.3.1.4 *Test Factors of Safety*: When spacecraft systems or subsystems are in the process of operational checkout and test with personnel in the area, the pressure in pressurized systems shall not be greater than that which allows a fracture mechanics factor of safety of at least 1.35 or a factor of safety of 1.5 based on ultimate strength. .

Under these conditions, no stress from other operations shall be allowed to reach the tanks (see Section 4.8.6 for dynamic operations).

At all other times, the maximum pressure shall not be greater than that which allows a factor of safety of 4.0 based on ultimate strength.

This requirement does not apply for the final pressurization for flight when the following constraints apply:

(1) The final pressurization shall be performed as late as possible in the schedule.

(2) Personnel access during and after pressurization shall be restricted so as to expose the minimum number of persons to the pressure hazard.

4.3.1.5 *Pressure Vessel Cleaning:* Fluids or solvents intended for use with pressure vessels shall be specifically approved by the Cognizant Engineer and Materials Engineer for the vessel or subsystem containing the vessel, and included in the fracture mechanics analysis.

Isopropyl alcohol or Freon 113 Chlorofluorohydrocarbons (CFCs) shall not be used on or in titanium pressure vessels at a pressure equal to or greater than one -third of the maximum allowable working pressure because of titanium susceptibility to stress corrosion.

4.3.1.6 *Flexible Lines and Hoses:*

4.3.1.6.1 Marking and Identification: Flexible pressure lines or hoses shall be marked with the following information:

(1) Function or service.

(2) Proof-pressure.

(3) Proof-pressure date.

(4) Due date for next proof-test (month and year).

(5) Maximum Operating Pressure (MOP).

4.3.1.6.2 Proof-Pressure Test: Flexible lines or hoses shall be proof-pressure tested to at least 1.5 x MOP at least once per year.

4.3.1.6.3 Restraint: Flexible lines used at pressures of 1.034 MPa (150 psig) or greater shall be restrained at both ends, and at maximum intervals of 1.8 meters (6 feet).

4.3.1.7 *Disconnecting Connections*: No pressure line or connection shall be broken, disconnected, or otherwise opened until positive verification of its vented status is made.

4.3.1.8 *Capping Lines:* The open end of disconnected lines in a pressure system shall be securely capped and warning placards installed at the pressure control panel.

4.3.1.9 *Warning Signs:* Warning signs shall be placed at points where they can be seen clearly by any person attempting to energize, pressurize, or operate a system containing disconnected lines.

4.3.1.10 *Repair and Maintenance:* The following requirements shall be observed when performing repairs or maintenance in pressure systems.

4.3.1.10.1 Personnel Qualification: Persons repairing or maintaining pressure systems shall be qualified for the specific pressures and fluids involved.

4.3.1.10.2 Decontamination: Contaminated sections of pressure systems to be removed, replaced, or serviced shall be decontaminated before exposure to the atmosphere.

4.3.1.10.3 Protective Equipment: Personnel involved in the repair or maintenance of pressure systems containing hazardous fluids or gases shall wear the appropriate protective equipment and be equipped with the proper respiratory equipment.

4.3.1.11 *Relief Valve Recertification/Requalification:* Relief devices shall be inspected and tested at least once per year to the levels specified in para. 3.9.2.8.4.

4.3.1.12 *Pressure Gauge Recalibration/Recertification:* Pressure Gauges shall be inspected, calibrated for accuracy over their ranges, and tested up to their highest gradation at least once per year.

4.3.2 Liquid Propellant Systems

A liquid propellant is a chemical whose properties are such that its decomposition or reaction with other propellants or chemicals provides a high energy thermal source for use in propulsion subsystems. Such materials are potentially dangerous to both hardware and to personnel because of their explosiveness, flammability, toxicity, reactivity, or corrosiveness.

The following requirements are established to protect pe rsonnel and hardware from propellant spills or other accidents.

4.3.2.1 *Personnel Familiarization:* Personnel involved with toxic fluids and gases shall be thoroughly familiar with all aspects of the handling, storage, and transfer of the propellant being used. This familiarization shall include material compatibility , toxic effects on the human body, flammability, and other physical properties that can affect hardware and personnel safety.

4.3.2.2 *Safety Equipment:* Appropriate personnel safety equipment shall be utilized for all operations involving liquid propellant systems. This may include some or all of the following: gloves, face shields, self-contained breathing equipment, complete protective garments or suits, communication equipment, safety glasses or goggles, cryogenic protective equipment, hard hats, etc.

4.3.2.3 *Toxicity*: Personnel shall not be exposed to concentrations of toxic fluids, propellants, or gases at levels greater than the threshold limit value (TLV) for eight-hour exposure permitted by the Occupational Safety and Health Administration (OSHA). The Material Safety Data Sheet (MSDS) shall be consulted for information regarding the characteristics, precautions required and exposure limits for the propellant to be used. See Section 4.3.2.6 for fire and explosion hazards.

4.3.2.4 *Repair, Servicing, and Maintenance:* Repair, servicing, or maintenance operations to propellant or other hazardous fluid systems (GSE or flight) shall be performed only by properly qualified personnel.

Reasonable efforts shall be made to d rain and decontaminate systems prior to any repair or maintenance operations. When work shall be performed on contaminated systems, personnel shall wear appropriate protective clothing and breathing apparatus.

Whenever possible, personnel should work ab ove hazardous liquid systems to prevent liquid drips or leaks from falling on personnel.

4.3.2.5 *Storage Areas*: Propellants and other hazardous fluids (liquid or gas) shall be stored in areas specifically authorized and designated for the storage of the specific fluid. The following requirements shall be observed:

(1) Storage areas shall be segregated and provide isolation from incompatible fluids.

(2) Storage areas shall comply with the quantity/distance requirements determined in NFPA 495, "Code for Manufacture, Transportation, Storage, and Use of Explosive Materials."

(3) Storage tanks and containers shall be verified to provide adequate ullage to prevent excessive pressure buildup due to ambient temperature conditions during the hottest days for the storage area. The annual highest temperatures shall be used for analysis because launch slips and other delays may require the fluids to be stored long beyond their intended storage period.

(4) Containers for flammable or explosive fluids shall be electrically grounded when flammable fluids or residual fluids are present in the container.

(5) For fluids stored with a cryogenic blanket or cover, an adequate supply of the thermal control cryogen (typically LN_2) shall be guaranteed. Contingency plans shall define the actions to be taken in the event the thermal-control cryogen supply is interrupted.

(6) Spill containment capabilities shall be verified adequate for the propellant type and quantity.

4.3.2.6 *Fire and Explosion Hazards*:. The propellants are generally chosen for their high energy content. As such, they tend to be highly reactive with each other and with contaminants or incompatible materials with which they may come into contact. Personnel handling propellants shall continually keep this in mind.

Material Safety Data Sheets (MSDSs) are available from the Safety Operations Section. To consult for specific information on the propellant to be used contact computer on-line access through JPL Netscape at http://www.hazard.com/

4.3.2.7 *Cleaning*: Flight and GSE systems shall be cleaned using approved procedures prior to exposure to flight fluids. If the flight fluid is reactive in nature, the system shall also be passivated prior to the introduction of the fluid.

Detailed parts shall be cleaned prior to assembly into a system so that all surfaces are wetted and flushed during cleaning. Items requiring multiple cleaning solutions shall be completely dried between the application of each solution of different chemical mixtures.

4.3.2.8 *Smoking:* Smoking shall not be permitted within a radius of 30 meters (100 feet) of any propellant storage tank or GSE, or on or around any test or launch facility except in specifically designated areas. This requirement applies both to fuels and to oxidizers.

4.3.2.9 *Inspections:* Inspections of GSE systems shall be made periodically to verify the continued acceptability of the GSE. The inspection period shall be determined based upon the frequency of service of the equipment, the external environment, and the nature of the fluid contained.

4.3.3 Hazardous Fluid Systems

Systems, subsystems, assemblies, components, instruments, or experiments containing fluids or gases which could be hazardous to personnel or hardware if released from their containers shall be handled with the appropriate precautions and constraints specified in Section 4.3.2. Examples of these items include chemical lasers , ammonia heat pipes, RTG gas exchange equipment, and cooling systems.

4.4 FACILITIES

4.4.1 Reviews

A review of all facilities used in the assembly, test, or evaluation of JCI's shall be conducted per Section 4.9.1. Among items covered will be the definition of the scope of activities within the facility, including a list of all operations and modes planned involving the hardware.

4.4.2 General Facility Practices

Facilities used for the assembly, inspection, or test of flight equipment shall meet the following general requirements.

4.4.2.1 *Cleanliness and Housekeeping:* Facilities shall be maintained clean commensurate with the requirements of the specific flight hardware:

(1) Cleaning shall be performed as often as necessary to maintain a clean and orderly work area.

(2) If multiple systems or projects are using a particular facility, all areas of the facility that can affect the hardware shall be maintained at the most stringent requirement level.

(3) Floors, lockers, or other storage areas shall be kept free of extraneous material.

(4) General cleaning operations shall not be performed while hazardous activities are being conducted in the area.

4.4.2.2 *Smoking, Eating, and Drinking*: Smoking, eating, or drinking shall not be permitted in any flight hardware assembly, inspection, test, or storage area.

4.4.2.3 *Garments:* Personnel shall wear the garments specified by the specific facility. The special garments may be for the purpose of protecting personnel in hazardous areas, or for protecting the flight hardware from personal clothing (Section 4.2.9.6).

4.4.2.4 *Overhead Water Systems:* Precautions shall be taken to protect JCI's from the potential of damage due to broken or leaking overhead fluid systems or normal/accidental discharge of automatic sprinkler systems. Precautions may include:

(1) Rerouting water systems.

(2) Relocating susceptible equipment.

(3) Protective shields, umbrellas, covers, etc.

(4) Temporary draining of overhead systems.

Suitable coverings shall be immediately available to cover JCI's in the event of an inadvertent rupture or discharge. Equipment that is unattended or not in use, shall be covered.

4.4.3 Clean Rooms

Clean rooms are designed to protect the flight hardware from the local ambient environment and shall be designed and operated in accordance with Federal Standard 209 or equivalent. In addition, the following requirements shall be followed to protect the hardware from damage caused by the clean room itself:

4.4.3.1 *Filter Test:* The efficiency of clean room filtration systems shall be verified periodically. The clean room shall be verified to meet the clean room filtration level established for each specific project.

4.4.3.2 *Filter Test Medium:* Clean room filters shall be tested using atmospheric air. Dioctylphthalate (DOP), or other condensible substances, shall never be used for testing clean room filters at any time during their fabrication or installation testing.

4.4.3.3 *Lubricants:* Lubricants shall be chosen to preclude outgassing or evaporating into the clean room.

4.4.3.4 *Paints:* Paints and other surface protection mediums for the clean room and for equipment in the room shall be verified not to outgas, oxidize, flake, or otherwise cause chemical or particulate contamination.

4.4.4 Fire Protection

4.4.4.1 *Sprinklers:* The JCI as a system shall be located only in areas which have no automatic water sprinklers or where the sprinklers are deactivated and drained, and other suitable fire protection is provided (see Section 4.4.4.2.). If this cannot be accomplished, a suitable barrier shall be employed to protect the equipment from accidental discharge. (Ref. Para. 4.4.2.4).

4.4.4.2 *Fire Extinguishers:* Existing portable hand-operated Halon (e.g. Halon 1211) extinguishers shall be available at all times beginning with the initial assembly and build up. In case of fire on or near the flight equipment, the Halon extinguishers shall be used as the first choice of extinguishing agent unless other types are specifically required due to the presence of unique materials requiring other agents. Once the fire is extinguished, personnel within the area shall be evacuated since continued breathing of Halon vapors may be undesirable.

The use of automatic Halon 1301 extinguisher systems is encouraged in all areas containing JCI's. The use of Halon as an extinguishing agent is encouraged because of its effectiveness in arresting flames without further damage to the hardware and its nontoxicity to personnel for short exposures. Because of the cessation of manufactured Halon, these type of fire extinguishers are no longer available. For the replacement of expended or out-of-calibration Halon extinguishers the JPL Fire Department should be consulted.

In all instances, personnel safety shall take precedence over facility or hardware safety. No attempt to use hand-held extinguishers shall be made if such action appears to compromise personnel safety.

WARNING
Halon fire extinguishers shall not be used directly on ordnance fires because the high combustion temperatures can cause the generation of highly toxic Phosgene gas ($COCl_2$).

4.4.4.3 *Fire Department Notification:* Plant Security and Fire Department personnel are notified of the presence of JCI systems or subsystems in a facility by the completion of the Flight Hardware Location Summary report issued, on a monthly basis, by the Systems safety Office,(see also Section 4.2.10.11).

4.4.4.4 *Prevention of Flame Spread:* The following guidelines shall be considered and implemented wherever reasonable and practicable in order to minimize the spread of flame or fire. They shall serve as evaluation items when assessing the acceptability of a building or facility for JCI activities.

4.4.4.4.1 Nature of Hazards: The various trough-like structures used to route and protect electrical cabling and fluid and gas piping runs can serve as unexpected channels for the spread of fire, flame, flammable materials, or heated air or gases. These structures include, but are not limited to:

trenches	raceways
tunnels	culverts
utility channels	gutters
troughs	ducts
conduits	pans

Such structures can act like chimneys, allowing strong drafts of heated air to carry burning materials rapidly from one location to another. They can also serve as inlet channels, supplying fresh air -- and thus oxygen -- to existing fires, as flow channels, allowing fuels, solvent, vapors, or flammable materials to run from one location to another, and as receptacles, allowing large pockets of flammable liquids, gases, or vapors to form or collect.

4.4.4.4.2 Reduction of Hazards: The spread of flame or fire by way of such structures described above can be reduced by several means, such as:

(1) Perforations and/or discontinuities. The introduction of perforations and/or discontinuities, as appropriate, along the pathways formed by these structures can serve to break up potential flows of liquids and gases. This technique could be applied to overhead conduits, troughs, pans, or supports carrying electrical cabling or piping. This technique could be implemented as short, discontinuous stretches of support, or by providing large vent and drain holes along the length of the support.

(2) Barriers or obstructions. The introduction of permanent, semipermanent, or temporary barriers or obstructions along pathways provided for electrical cabling or for piping can serve to eliminate potential flows of liquids, gases, flame, or fire. Such barriers or obstructions should be placed as follows:

- (a) At points of penetration through building or room walls, ceilings, or roofs.
- (b) At points of penetration through floors where large open spaces or open pathways exist on both sides.
- (c) At suitable intervals along stretches of the trough-like structures. The term "suitable intervals" is defined as follows:
  - (i) Two meters (6 feet) or less where cable or piping runs pass through areas which are highly populated or where fuels or other flammable materials are handled in quantity or where flammable vapors or gases may collect. One example would be where cable or piping utility channels are cut in the floors of hangars or workshops.

(ii) Thirty meters (100 feet) or less where electrical cabling or piping is routed through remote or isolated areas or across open fields and where exposure of personnel or equipment is minimal.

(iii) Two to thirty meters (6 to 100 feet) as appropriate in trade-off between the potential hazards identifiable and the safety required by the proximity of personnel and equipment.

Construction methods and materials for barriers or obstructions may include, but are not limited to:

(1) Sand bags.

(2) Dirt fill, dikes, or dams.

(3) Conventional masonry materials and technique s.

(4) Foam-in-place fire-retardant materials SPECIALLY DESIGNED FOR SUCH SERVICE.

(5) Precut or field-cut blocks of fire-retardant materials SPECIALLY DESIGNED FOR SUCH SERVICE.

4.4.5 Explosive Safe Areas

4.4.5.1 *Doors:* Personnel doors shall open outward and shall not be fastened closed with locks or other restraints other than panic bars or other quick -releasing devices which will allow egress at any time.

Such doors shall be provided with safety ramps or stairways [with handrails if over 1.2 meters (4 feet) above ground].

4.4.5.2 Escape Routes. Pathways to and from exit doors shall remain free from obstructions at all times.

4.4.5.3 Waste Materials. Waste materials, such as rags, paper, etc., shall be kept separated from each other. Each category shall be placed in approved containers , properly marked, and stored outside the building.

4.4.6 Lightning Protection

Direct lightning strikes are obviously extremely hazardous to spacecraft, test and launch equipment, and to personnel, but even nearby strikes can be very damaging to peripherals, electrical or electronic circuitry. The enormous electrical currents present in lightning strikes create strong magnetic fields that can induce significant voltages in conductors that may be located many feet from the actual strike. The induced voltages and resulting currents can be destructive or degrading to circuits.

Faraday shields, such as those formed by the metal or electrically conductive structures of most buildings, the launch vehicle fairing, and the metal or electrically conductive walls and structure of transport trailers, offer protection from lightning-induced electrostatic fields, but are somewhat less effective in the attenuation of lightning-induced magnetic fields.

The following precautions shall be taken to the maximum extent practicable to protect the spacecraft and critical test and launch equipment in areas where lightning may be encountered. In general, the more precautions applied, the greater the protection. In cases where one superior protective measure is taken, others might be unnecessary.

4.4.6.1 Shielding. Susceptible hardware should be enclosed in a shield. The most preferable enclosure would be constructed from a magnetic material, such as iron or steel, and would therefore provide protection from magnetic fields.

4.4.6.2 Location in Building. Susceptible hardware should be kept near the center of a building, particularly where lightning conditions are a potential threat.

4.4.6.3 Location From Conductors. Susceptible equipment should be located as far as practicable from any electrical conductor or conductive structure which might carry a portion of the lightning discharge current.

4.4.6.4 *Building Grounds:* Susceptible equipment shall be disconnected from the building ground whenever there is reason to believe that electrical storm activity may be present in the area.

4.4.6.5 *Dedicated Grounds:* Susceptible equipment shall remain connected to a ground IF the equipment ground:

(1) Is dedicated and is separate from the building ground, and

(2) Has no long runs of branching conductors, and

(3) Is located under or nearly under the susceptible equipment.

4.4.6.6 *Connected Equipment:* Power, control, instrumentation, and test conductors associated with test equipment , support equipment, computers, recorders, and similar devices should be disconnected from the JCI when not in use.

Connections to roof-mounted items such as antennas deserve particular attention. Ideally, such items shall be disconnected at both ends. Where this is impracticable, attenuation and arresting techniques should be employed on the lead -ins. Such techniques include the use of ferrite isolation devices, spark gaps, grounded coaxial outer shells at the inside of the building end of terminations, coaxial to wave guide transitions, filters, and electrical dc blocks.

Attention to any other cabling which may exit the building, such as that in cable trenches or trays, is especially important whenever possible. Such cabling should be disconnected from susceptible equipment and the disconnected end shall be removed physically to a distance of several feet from equipment or electrically conductive structures.

4.4.6.7 *Crane Hooks:* Crane hooks and wire cables shall be disconnected from susceptible equipment and moved to a distance greater than 3 meters (10 feet) from the equipment.

4.4.6.8 *Cone of Protection:* Susceptible hardware shall be located inside a cone of protection of lightning rods, but (ideally) greater than 3 meters (10 feet) from the downcomers that lead into the earth.

4.4.6.9 *Proximity to Earth Ground*: Leads or cables which must remain connected shall be routed through areas which are at least 3 meters (10 feet) from the places where lightning energy might enter the earth.

4.4.6.10 *Twisted Conductors:* Any external leads or cables which must remain connected shall be maintained in a twisted or bifilar configuration so that any voltage induced into one wire by a magnetic field will be canceled by an opposing voltage induced at the same time in the return wire.

4.4.6.11 *Ground Impedance:* The impedance of lightning strike downcomers shall be maintained at the lowest practicable value. Sharp bends in the downcomers shall be avoided.

4.4.6.12 *Timing of Operations:* Operations involving susceptible equipment shall be planned for the times when there is the lowest probability of electrical storm activities. Current weather reports and forecasts shall be utilized in the assessment of potential electrical storm activities.

4.4.6.13 *Frequency of Occurrence:* The occurrence of lightning across the United States varies considerably. Past history indicates the following general levels of incidence in areas of interest to JPL:

(1) JPL Oak Grove facilityMain lab
Mesa and higher altitudes Occasionally

(2) WR (Vandenberg Air Force Base) Rarely

(3) ER (Cape Canaveral and Kennedy Space Cen ter)
Most prevalent in United States

4.4.7 Earthquake Protection

4.4.7.1 *Hardware Protection:* The following requirements, specified elsewhere in this document, are tabulated here to provide a cross-reference for requirements specifically related to earthquake protection:

Topic	Section
Storage	4.2.2.4
Falling Objects	4.2.2.5
Work Surfaces	4.2.2.6
Work Areas	4.2.2.7
Lateral Stability	4.2.2.8
Tie-Downs	4.2.2.9
Suspended Equipment	4.2.3.1.2
(Crane) Earthquake Inspection	4.1.3.6.6

4.4.7.2 *Program-Critical Facilities and Equipment:* Many things besides the JCI have a significant influence on program success. Items of particular concern include, but are not limited to the following:

(1) DSN antennas and related facilities.

(2) Command facilities in SFOF and elsewhere.

(3) Computing facilities.

(4) Data-recording facilities.

Due to their essentiality, it is imperative that all due precautions practicable be employed to minimize vulnerability to earthquake disruption of operations. Techniques that should be employed to minimize Project interruption due to earthquakes are:

(1) Ruggedize all equipment and facilities to the maximum practicable degree.

(2) Consider alternate back-up facilities a sufficient distance apart to allow relatively uninterrupted command, tracking, recording, and data processing during mission-critical times.

4.4.7.3 *Resumption of JCI Operations:* Immediately following any earthquake of significant magnitude, JPL's Emergency Response Team (ERT) assembles at the Emergency Operations Center. Specialists from the Safety, Facilities, Fire and Security Departments begin a systematic inspection of laboratory facilities to determine whether they are safe for occupancy. As areas containing JCI's are cleared for re-occupancy, the ERT system safety representative shall notify the cognizant engineer that his JCI area has been cleared. Prior to resuming JCI operations, the cognizant engineer shall ascertain any associated action which is deemed necessary to assure the safety of the JCI.

4.5 IONIZING RADIATION

4.5.1 Policy

At the Oak Grove facility and at any other location/facility under the purview of JPL, centralized control will be exercised over the procurement, storage, transportation, use, and disposal of ionizing radiation sources to ensure safe practices and operations and to preclude unnecessary exposures to personnel. In this context, ionizing radiation sources include radioactive materials and radiation-producing machines or devices. All activities involving radiation sources shall be conducted in such a manner as to conform to all pertinent Federal, State, and local regulations/controls, and sound radiation safety practices.

4.5.1.1 *Use Authorization:* JPL Radiation Safety Committee (RSC) authorization is required for the procurement, storage, transportation, use, and disposal of ionizing radiation sources at any location/facility under the purview of JPL, or where such sources will be handled or otherwise used by JPL personnel or contractors. A Use Authorization Request form will be completed by the proposed radiation source custodian and forwarded to the JPL Radiation Safety Officer (RSO) to initiate the use authorization process, prior to the procurement or use of radiation sources. The forms listed below are available from the JPL RSO.

(1) Radioactive Materials Use Authorization Request

(2) Ionizing Radiation Machine Use Authorization Request

The JPL RSC shall review the application and, if approved, the RSO will obtain any required institutional or on-site authorization or licensing from appropriate regulatory agencies.

The Use Authorization process is more completely described in the Radiation Safety Program Plan, JPL Document D-11634.

4.5.1.2 *Use of Radioactive Materials in Flight Hardware:* Launch of radioactive materials on spacecraft requires notification to NASA headquarters, Code Q. Reporting, analysis, and approval requirements for the launch of such materials will vary depending upon the type and quantity of radioactive material proposed for use. These requirements are described in NASA Policy and Guidelines (NPG) 8715, NASA Safety Policy and Guidelines, Chapter 5. At JPL, the coordination of these requirements is governed by the Launch Approval Engineering (LAE) process and implemented by the Launch Approval and Policy Planning Group (LAPPG) in the Mission and Systems Architecture Section.

4.5.1.3 *Ionizing Radiation Source Use:* The JPL RSC shall review procedures for the proposed use of ionizing radiation sources as part of the Use Authorization process. The RSO will provide for area surveys and assessments, and operations surveillance as deemed necessary by the RSC, through the Safety Operations Section.

4.5.1.4 *Non-JPL Locations:* The JPL RSO will provide for and coordinate local authorizations as required for JPL operations at non-JPL locations, and support those operations as deemed necessary by the project or the JPL RSC. When operations involving radioactive materials occur at locations other than JPL, the radiation safety requirements of that facility shall also apply, and shall be enforced by the local radiation safety organization. In cases of conflict between the JPL and non-JPL organization requirements, the more conservative requirement shall be observed, whenever operationally feasible. Where this is not possible due to operational constraints or hardware requirements, the JPL RSO will coordinate with the facility radiation safety organization to develop a plan of operation that will satisfy the local requirements.

4.5.1.5 *Doses and Dose Rates: t*he JPL Radiation Safety Program notes the Caltech guideline that no Caltech employee should be deliberately exposed to more than 10% of a legal limit of ionizing radiation dose unless it is demonstrated that the employee is performing an essential operation and there is no practicable engineering method of reducing the dose. Application of this guideline to JPL personnel shall be the responsibility of the JPL RSC.

Personnel radiation exposures shall in all cases be kept below the established regulatory limits. Work practices and procedures shall be developed to maintain exposures to personnel at levels that are As Low As Reasonably Achievable (ALARA).

4.5.1.5.1 Controlled Areas: Areas where an individual could receive radiation doses equal to or greater than 2 millirem (mrem) in an hour, or 100 mrem in 7 days, or 500 mrem in one year shall be controlled for radiation safety. Personnel working within the controlled area may be required to wear film badges and/or other personnel dosimetry devices as specified by the JPL RSO in the Use Authorization.

4.5.1.5.2 Radiation Areas: Areas where an individual could receive radiation doses equal to, or greater than, 5 mrem in an hour or 100 mrem in 5 days shall be posted as radiation areas. Personnel and area monitoring and access control requirements shall be specified by the RSO as part of the Use Authorization.

4.5.1.5.3 Radiation References:

Further information on ionizing radiation may be found in the JPL Radiation Safety Program Plan. The regulatory requirements forming the basis of the JPL Radiation Safety Program are described in:

(1) California Administrative Code - Title 17, Chapter 5, Subchapter 4, "California Radiation Control Regulations". (CCR: Title 17)

(2) California Administrative Code - Title 8, "Industrial Relations" (CCR: Title 8).

(3) Code of Federal Regulations - Title 10, "Energy"(10 CFR).

(4) Code of Federal Regulations - Title 21, Subchapter J, "Radiological Health" (21 CFR).

(5) Code of Federal Regulations - Title 29, Chapter XVII, Part 1910 "Occupational Safety and Health Standards" (29 CFR 1910).

(6) Code of Federal Regulations - Title 49, Parts 100 - 177 "Transportation" (49 CFR).

4.5.1.6 *Handling and Use:* The handling and use of all radiation sources shall be performed by or under the supervision of individuals authorized by the JPL RSC and the radiation safety organization of the licensed institution. Surveillance shall be provided as deemed necessary by the JPL RSC.

4.6 **NONIONIZING RADIATION**

4.6.1 Radio Frequency (RF) Radiation

4.6.1.1 *Description:* Radio Frequency transmitters, as well as experiment and support equipment electronics, can emit RF energy at frequencies and levels which can be damaging to human tissue and hardware. Some frequencies (X-band) give warning of exposure by causing the surface of the skin to heat up, but other frequencies (S-band) cause damage to internal organs without sensation.

4.6.1.2 *Exposure Limits:* Personnel at JPL or at off-site locations shall not be exposed levels of RF exposure above those recommended by the American National Standards Institute (ANSI) C95 Subcommittee on Radio Frequency and Microwave Safety, as described by ANSI C95.1.

4.6.1.3 *Area Control:* Personnel shall not work in front of a transmitting antenna or other radiating device when the transmitter or microwave generator is in operation. A controlled area shall be established to prevent personnel from inadvertent exposure. An RF absorbing shield or "top hat" shall be used to preclude energy overflow from transmitting antennas used in confined facilities.

4.6.1.4 *Area Assessment:* Radiation levels produced by equipment shall be quantitatively assessed to assure that personnel exposure limits are met. RF measurements and area assessments for personnel protection are performed by the Industrial Hygiene Group of the Safety Operations Section.

4.6.2 Lasers

4.6.2.1 *Description:* Lasers may cause injury to personnel by damage to the eye or skin tissue. A burn can result within nanoseconds from the concentration of great amounts of energy on human tissue. The majority of eye injuries are irreversible, producing at a minimum the permanent loss of some visual capabilities, depending upon the location and extent of the injury.

4.6.2.2 *Authorization:* JPL Laser Safety Officer (LSO) authorization is required for the procurement, storage, transportation, use, and disposal of laser sources at any location/facility under the purview of JPL, or where such sources will be handled or otherwise used by JPL personnel or contractors. The authorization process is described by the JPL Laser Safety Program Plan, and is part of the Operational Safety Review (OSR) process. A Laser Safety Data Sheet available from the LSO will be completed by the intended user of the laser and provided to the LSO prior to procurement of the laser or laser system.

4.6.2.3 *Classification:* Classification of lasers is accomplished by grouping according to potential hazard for injury. Lasers or laser systems purchased from commercial vendors are classified by the manufacturer commensurate with the potential hazard inherent in the intended function of the laser or laser system. Purchased lasers that have been modified or reincorporated into different systems, or lasers built by or lasers systems assembled by experimenters or researchers for specific purposes must be classified by the JPL Laser Safety Officer (LSO). In all cases, the laser classification scheme method follows that recommended by ANSI Z136.1, “American National Standard for Safe Use of Lasers” or ANSI Z136.2 “American National Standard for the Safe Use of Optical Fiber Communications Systems Utilizing Laser Diodes and LED Sources.”

4.6.2.4 *Eye Protection:* The need for eye protection will be assessed by the LSO based upon the laser safety data sheet and the intended laser operation, as described by the user. Eye protection will be approved by the LSO and worn by all personnel in the laser operating area when required.

4.6.2.5 *Reflective Surfaces:* Reflective surfaces in the area of laser operations shall be covered or dulled to prevent reflection. In addition, a beam-absorbent material shall be placed in the path of the beam to prevent traveling further than necessary.

4.6.2.6 *Area Control:* Many types of lasers and laser systems produce ancillary hazards when operating, such as high levels of ultraviolet radiation or RF radiation, or involve the use of hazardous chemical agents such as organic dye compounds. For this reason, the area in which lasers are to be operated shall be approved by the Laser Safety Officer and the Safety Operations Section via the OSR process. Appropriate access controls shall be established to prevent non-operating personnel from inadvertent exposure to the laser beam.

4.6.2.7 *Medical Surveillance:* Users of certain types of lasers are subject to medical surveillance. Specific requirements are described in the JPL Laser Safety Program Plan.

4.6.3 Ultraviolet Light

4.6.3.1 *Description*: Overexposure of skin or eyes to ultraviolet light causes burning. Under Earth's atmosphere at sea level near noon on a clear summer day, exposed skin surfaces receive approximately 20 mW/cm2 of ultraviolet light. This level is sufficient to begin to cause perceptible erythema (reddening) of untanned skin in 18 minutes.

4.6.3.2 *Exposure Limits:* Personnel shall be provided with proper skin and eye protection when in the vicinity of ultraviolet equipment operating at levels greater than 0.1 mW/cm2 for an eight-hour continuous exposure.

4.6.4 Ultrasonic Sound

Ultrasonic frequency sound generators shall be controlled and limited in the vicinity of the JCI or other sensitive hardware.

Ultrasonic frequency sound can affect sensitive material located on the JCI or on other sensitive hardware. Ultrasonic sound can cause nerve irritation and ear damage to personnel.

4.6.5 Audio Sound

Ambient noise levels shall be kept below 85 dB in areas where activities are being conducted without appropriate ear protection.

4.7 ELECTRICAL AND MECHANICAL TEST

4.7.1 Electrical Test Equipment

4.7.1.1 *Approval:* Test equipment to be connected to any JCI shall have the prior approval of each affected cognizant engineer before connection is made to ensure the compatibility of the internal circuitry with the electrical characteristics of the test equipment (e.g., grounding, impedance, voltage, or current). An “end to end” electrical interface test shall be conducted and shall be verified for Flight Hardware/EGSE prior to pre-launch activities at any given launch site (see also paragraph 4.1.4.1.3 of this document),

Distracting noise is a hazard in areas where sensitive or critical operations are being conducted. Frequent or continuous exposure to high noise levels without proper protection will cause permanent loss of hearing over a period of time.

4.7.1.2 *Grounding:* The case of each electrical tool or instrument shall be connected to the JCI common point ground, even if the tool or instrument is isolated from the power source through a transformer.

4.7.2 Breakout Boxes

Breakout boxes shall be qualified (verified for proper circuit continuity, and isolation) prior to use with JCI's.

Extreme care shall be observed in the use of breakout boxes to avoid accidental short circuiting or harmful open circuiting of any signal path.

4.7.3 Explosive Environments

Non-explosion-proofed equipment may be used in areas normally requiring explosion-proof equipment provided that the following criteria are followed:

(1) The environment is verified to be free of potentially explosive vapors.

(2) Equipment in the area is not inherently explosive (e.g., Solid Rocket Motors).

(3) The energized equipment is continuously attended by operating personnel.

(4) The equipment or equipment rack can be powered down by a single switch or power disconnect.

(5) The approval of the appropriate Safety authority (e.g. Range Safety at ER or WR) is obtained.

4.7.4 Electrical Test Procedures

Electrical integration and test procedures shall provide for sufficient configuration verification and continuity checks to assure that the circuitry is correct prior to the application of power to the circuit. See Section 4.1.5 for more procedure requirements.

4.7.5 Hazardous Commands or Stimuli

Appropriate caution statements shall be included in the test procedures when conditions exist for the possibility of incorrect power or stimulus application, or the transmission of hazardous commands.

4.7.6 Connectors

4.7.6.1 *Mating and Demating:* Electrical connectors shall not be joined or separated when energized. Power connectors must be chosen to be “scoop-proof”(cannot be angularly forced into an error pin contact), keyed and sized so as to prevent mismating.

4.7.6.2 *Inspection:* Connectors shall be inspected for cleanliness and for pin alignment prior to each mating.

Connectors requiring cleaning shall be cleaned using the appropriate specified approved procedure.

Bent pins shall be straightened only by cognizant connector personnel or by a specifically authorized designee.

4.7.6.3 *Authorization:* The mating or demating of flight connectors shall be performed by specifically authorized personnel.

4.7.7 Cables

Flight cabling shall be fabricated, tested, cleaned, outgassed, stored, moved, or otherwise handled only by certified personnel using techniques and practices specified in D-8208 (DM509306), Volume 2, "Electronic Equipment and Cabling Design and Fabrication Requirements and Processing Techniques." Extreme care should be exercised when selecting a thermal/vacuum system to “bake-out” flight cables. Cross contamination to flight sensitive hardware (optics, critical surfaces) could result in a degenerated component or subsystem.

4.8 ENVIRONMENTAL TEST

The requirements of this section shall apply to all facilities and activities involved in environmental testing of JCI.

Note: The JPL Environmental Test Laboratory (ETL) facilities and personnel are maintained to the standards required for JCI. See System Procedure: Use of Non-Environmental Test Lab Facilities for Environmental Testing for the JPL use of other testing facilities (for the application of environments) that are outside the jurisdiction of the ETL.

4.8.1 Definition

Environmental testing is the intentional application of any universal environment that has the potential of damaging the hardware, regardless of the location of the test facility or the phase of the hardware life cycle. This includes environments imposed for processing, as well as qualification or acceptance testing.

4.8.2 Reviews

The Facility Safety Survey and the Operations Safety Survey specified in Section 4.9 shall be completed prior to the conduct of environmental test(s) (see Section 4.1.1 for applicability). An ESD survey shall be performed if necessary.

4.8.3 Handling and Safety Responsibility

The cognizant hardware organization shall be responsible for the handling of all JCI's while in the environmental test facility. This responsibility shall include the attachment of the JCI to any test fixtures.

4.8.4 Procedures

Environmental testing of JCI's shall be conducted in accordance with approved written procedures. See Section 4.1.5.7 for approval requirements.

Changes to procedures shall be documented in writing prior to implementing the change and shall be approved by the original approval authority. Facility detailed test procedures and JCI functional test procedures shall define the specific contingency actions to be taken in the event of a test anomaly or malfunction.

4.8.5 Test Surveillance

An experienced, certified test facility operator(s) shall be in attendance at all times that the JCI is in test at conditions other than an ambient environment. If the JCI is operating, an experienced, qualified hardware operator(s) for the test item shall also be in attendance (Section 4.10.3).

Operators shall understand the immediate contingency actions to be taken to return the test facility and flight hardware to a safe state in the event of a facility or test article malfunction.

4.8.6 Pressurized Systems

Due to the additional stresses that dynamic environmental tests induce into the flight hardware being tested, the following special considerations and limitations shall be imposed on the allowable pressures for pressurized systems (see Section 4.3 for nondynamic testing).

4.8.6.1 *Special Precautions:* To the maximum extent practicable, critical areas of the pressurized system, such as pressure vessels, feed lines, and regulator assemblies shall have appropriate protective covers installed to minimize possible damage from sources external to the system.

4.8.6.2 *Minimum Safety Factors For Dynamic Test:* During operations or tests that might induce additional stress into a pressure vessel or assembly beyond that imparted into the material by virtue of its being in a pressurized state, the pressure in the vessel shall be no greater than one-third of the design working pressure that would achieve a factor of safety of 1.35 based on fracture mechanics for the vessel. Examples of such tests are vibration, acoustics, or shock tests.

For portions of the pressurized system other than the pressure vessels, the pressure shall not be greater than that which allows a factor of safety of 4.0 based on ultimate strength.

4.8.7.1 *Transducers:* Control and monitor transducers used for acceptance testing shall be the same type, installed at the same locations, and interconnected in the same manner as those used for qualification or type approval testing of a like test article.

4.8.7.2 *Calibration*: Control and monitor transducers used for testing JCI's shall be in valid calibration status.

4.8.7.3 *Overtest Protection:* The test laboratory shall provide adequate protective devices for use during the tests to limit overtesting.

These overtest protective devices shall be independent of the normal automatic controlling devices and shall be demonstrated to be operable prior to each test or test series.

4.8.7.4 Emergency Shutdown: Emergency shutdown buttons or switches shall be provided to permit dynamic tests to be immediately terminated by the test director and/or by specified observers.

The shutdown action shall not impose stresses or transients greater than originally planned to be imposed by the normal conduct of the test.

Electronic/computer controlled test equipment shall have a mechanical emergency shutdown capability in case of failure of electronic/computer controls (peak limiters).

4.8.7.5 *Interlocks:* Redundant monitors shall be provided which will remove power from the JCI when unacceptable conditions could rapidly occur during test, e.g., instruments or electronics which can only be operated below certain vacuum or thermal levels.

4.8.8 Test Fixtures

Environmental test fixtures and adapters shall be verified by analysis and test for adequate fit and support of the JCI in the intended environments. The integrated facility/fixture combination shall be demonstrated to be capable of performing within set limits over the entire environmental range to which it will be exposed during the JCI test.

4.9 REVIEWS/SURVEYS

The following surveys shall be conducted prior to the assembly, inspection, transportation, or test of JCI's. The surveys may be conducted consecutively, provided that appropriate emphasis is given to each aspect of each individual survey. The level of formality of the process shall be as appropriate and necessary for the hardware and is determined using the applicability table in the survey questionnaires, which can be found, electronically, by entering Netscape and logging into http://forms/.

As long as JPL is responsible for the hardware, the requirement for performing Safety Surveys is in effect. The intention of the requirement to conduct Safety Surveys at JPL and at non-JPL facilities is to ensure the Project Manager fully understands all environments and operations to which his/her hardware will be exposed, and that all necessary and appropriate precautions have been implemented. The term "Hardware" includes items of significance that will be delivered to JPL in support of JPL's commitments (.e.g. science instruments).

Attendees at the survey meetings at remote sites (non-JPL facilities) is a matter of judgment. The expertise represented by the named functions can be represented by fewer people. The nature of the activity determines the specific representation required, but the intent of the survey is to remain undiluted.

4.9.1 Facility Safety Survey

A Facility Safety Survey shall be conducted for facilities used in the test or evaluation of JCI's (see Section 4.1.1 for applicability).

A Facility Safety Survey questionnaire shall be completed and approved as a part of the survey. The completed and approved questionnaire (JPL Form 2002 for the Facility Safety Survey, and JPL Form 2003 for the Operations Safety Survey) will be retained in the System Safety Office Library. The Survey forms shall be retained for the duration of the Project.

An ESD survey per Paragraph 4.9.5 shall be conducted in conjunction with the facilities survey. It is not necessary that the ESD survey be done at the same time as the facilities survey, however, it is recommended that the ESD survey be accomplished prior to any formal reviews so that results may be reported at the review.

4.9.1.1 *Scheduling:* Facility Safety Surveys shall be completed not more than two months prior to facility use for JCI activities. In scheduling the surveys, consideration shall be given to the urgency of the project schedule to assure that the survey is held with sufficient lead-time to allow completion of action items which might be generated. Previous information from regular (annual or other) surveys can be taken into consideration to minimize repetition.

4.9.1.2 *Attendees:* As a minimum, attendees at the Facility Safety Survey shall include:

(1) Cognizant hardware engineer (or a typical "user" Cognizant Engineer if survey is not for a specific JCI).

(2) Cognizant facility personnel.

(3) Project representative (division or project office, as appropriate for this activity). Cognizant hardware engineer may also act in this capacity.

(4) JPL Systems Safety Office Engineer.

(5) Safety Operations Section Representative (if potential hazards to personnel are involved). This role may be assumed by the SSO engineer.

(6) Quality Assurance representative.

(7) JPL (or external) Environmental Test Laboratory representa tive (for environmental tests).

(8) Others as appropriate for the activity.

4.9.1.3 *Agenda:* If a formal project review is being held in addition to the Facility Safety Survey, the following topics, as a minimum, shall be included in the agenda:

(1) Definition of the scope of activities involving JCI hardware.

(2) Facility certification/validation status.

(3) Facility operator certification/checkout.

(4) Facility procedure status (released, approved).

(5) Facility contingency/emergency planning.

(6) Facility capabilities vs. test requirements.

(7) Facility configuration documentation status.

(8) Summary of the Facility Safety Survey.

4.9.2 Operations Safety Survey

A survey of the JCI and personnel readiness for the activity shall be conducted just prior to activities involving JCI's. An Operations Safety Survey questionnaire shall be completed and approved as part of the review (see Section 4.1.1 for applicability). The survey may cover a single activity, or a series of the identical activities. It is recommended that the review be held at the site of the operation. In the case of continuing activities in a particular area, the survey shall be conducted at least once per year, or sooner if the scope of the activities changes. It is the intent of the Operations Safety Survey to provide an Operations Safety Analysis of potential hazards that could be produced between the Facility, the environmental equipment, the support equipment, the JCI and personnel involved within the operation. Such hazards will be eliminated or controlled to an acceptable level and approved by the Operations Safety Survey Team.

4.9.2.1 *Scheduling:* The Operations Safety Survey shall be held when the facility, instrumentation, documentation, and cognizant personnel are fully ready for the activity.

4.9.2.2 *Attendees:* As a minimum, attendance of the following personnel shall be required at the Operations Safety Survey:

(1) Cognizant hardware engineer.

(2) Cognizant facility personnel.

(3) Project representative (division project representative or project office, as appropriate for hardware/level of test). (Cognizant hardware engineer may serve in this capacity.)

(4) Quality Assurance representative.

(5) JPL Systems Safety Engineer.

(6) Safety Operations Section representative (if any personnel hazards are involved). This role may be assumed by the SSO representative.

(7) Environmental Requirements Engineer.

(8) Others as appropriate for the activity.

4.9.2.3 *Agenda:* If a formal review is being held in addition to the Operations Safety Survey, the following topics, as a minimum, shall be included in the agenda:

(1) Definition of the scope of activities involving JCI's.

(2) Activity objectives and requirements (established and approved).

(3) Facility qualification and readiness (verified).

(4) Flight hardware readiness for the activity.

(5) Configuration documentation status.

(6) Test team or operator readiness (certification, checkout, etc.).

(7) Procedure(s) readiness (approved, released).

(8) Resolution of the Operational Safety Analysis Hazards.

(9) Contingency planning (complete).

(10) Summary of the Operations Safety Survey.

4.9.3 Transportation Safety Review

A Transportation Safety Review shall be conducted prior to the transportation of JCI's at the subsystem level or above. The review shall establish the adequacy of all handling and shipping equipment, lifting devices (including elevators, cranes, hoists, slings, chains, etc.), containers, operations, precautions, vehicles, environments, instrumentation, procedures, and personnel qualifications to protect the item.

As a minimum, attendees at the Transportation Safety Survey should include:

(1) Cognizant JCI Engineer.

(2) Project Representative (Division or Project Office, as appropriate for this activity).

(3) JPL Systems Safety Engineer.

(4) Transportation Office Representative.

(5) Security Services Representative

(6) Quality Assurance Representative.

(7) Environmental Requirements Engineer.

(8) Mechanical Engineering and Instrumentation personnel as required.

A Transportation Safety Checklist (JPL Form 2439) shall be completed and approved as part of the review.

4.9.4 Safety Surveys Minutes

4.9.4.1 *Minutes*: Mintues from each one of the Safety Surveys (Facility, Operations and Transportation) shall be drafted by a designated member of the respective Safety Survey team. Any Action Items, arising from the Survey, be assigned and closed out, to a point of satisfaction, before proceeding with any test or transportation.

4.9.5 ESD Survey

An ESD survey shall be conducted by the JPL ESD Control Engineer, in a facility whenever ESD vulnerable JCI's are being fabricated, tested or otherwise processed. The survey shall be repeated annually or sooner if significant modification is made to the facility or to the JCI and its test equipment.

An ESD Control Survey Form shall be completed and signed as part of the review (See JPL D-1348 Appendix ‘B’)

4.10 PERSONNEL

4.10.1 Training and Certification

Personnel shall be trained and qualified for the operations and tasks which they are expected to perform on JCI's. The training and verification may be formal or informal, depending on the task and facility or field site requirements. The following are current examples of each type, but requirements may change with time, and from field site to field site.

4.10.1.1 Formal. Examples of tasks requiring formal training and certification of personnel are:

(1) Propellant handling and other hazardous training at launch sites.

(2) Soldering, crimping.

(3) Mechanical assembly.

(4) Welding.

(5) Welding inspection.

(6) Fracture mechanics crack inspection.

(7) X-ray operation.

(8) Flight connector mating/demating.

(9) Electrostatic discharge (ESD) sensitive operations.

4.10.1.2 Informal/Local. Examples of tasks requiring informal or local checkout and certification of personnel are:

(1) Crane operators (on each crane at each site).

(2) Fork lift operators.

(3) Environmental test operating technicians.

(4) Facility door operation.

(5) Pneumatic or liquid control systems.

(6) Hydra-Sets.

4.10.2 Extended Shifts

The work hours of personnel involved in the testing or operations of JCI's which are vulnerable to damage by operator or test operations error shall be limited. Due to the value and sensitivity of JCI's, steps shall be taken to guard against fatigue errors. The following requirements shall apply to extended time operations:

(1) Operations shall be planned for no more than 8 -hour shifts, 40-hour weeks.

(2) The test conductor may approve extended work shifts up to a maximum of 12.5 hours per day for five consecutive days, provided the test conductor is convinced that fatigue is not a problem.

(3) Work time exceeding 12.5 hours in a single day for any person shall be approved in writing by the project manager. Such extension shall not exceed a total of 16 hours in a single day.

(4) Extended operations in excess of five days in any one week shall be approved in writing by the project manager.

NOTE: Special activities which require 24-hour operation and have approved extended work-shift policies established (e.g., Thermal Vacuum testing) are exempted from the 5-day limit for up to 300 hours (12.5 hour/days).

(5) Total hours in any 7-day period shall not exceed 62.5 hours without the written approval of the cognizant program office Assistant Laboratory Director. Only two successive weeks of 62.5 hours shall be allowed.

(6) Each work shift shall be separated by a minimum of 10 hours.

Activities occurring at locations other than JPL -Pasadena shall be governed by the more conservative of the field location rules or the above rules.

4.10.3 Operating Equipment Surveillance

JCI's shall not be left operating while unatte nded (Section 4.8.5).

An exception to this requirement is permitted if operating parameters and environment are stable and constant and if an "unattended" mode of operation that automatically removes power from the JCI in the event of abnormal JCI or environmental equipment performance is incorporated into the support equipment. An example of this is the "Outgassing" or volatile ester removal during a thermal/vacuum bake-out from critical optical components where contaminants are of concern. The cognizant Section Manager and the Project Manager shall specifically approve the intended mode of operation.

Where unattended operation is desired for long duration tests such as burn-in or other ambient environment activities, the Project Element Manager and the Project Manager (or equivalent), shall specifically approve the test plan prior to the test.

4.10.4 Buddy System

The JCI shall never be left attended by only one individual.

When one of the buddies, if only two are present, must leave for a break, restroom, etc., a third, approved individual shall be called in to accompany the remaining buddy. If this is not practical, then the JCI must be secured from unauthorized access and both buddies shall leave.

The practice of sealing the door of a thermal/vacuum chamber with a QA seal and then leaving only one person at the site is a violation unless the chamber or like container is locked. A seal, with no lock, would only provide after-the-fact indication of unauthorized entry.

The buddy system is to be implemented at the stage of development when the cognizant section manager declares the hardware to be flight critical.

It is recommended that the buddy system also be used at lower levels of assembly for critical items, such as optics, sensor arrays, sensitive components, etc. The manager responsible for the hardware is responsible for determining the need at this lower level of assembly.

The buddy system consists of two or more people.

At least one of the two has to be knowledgeable about or associated with the JPL critical item to be tested.

The second person shall be one who is approved for such activity by the cognizant test article engineer. This may be a QA or Reliability person.

The two are not to be out of sight from one another at any time, and each shall be aware of what the other person is doing.

Security guards are not candidates for qualifying as one of the buddie s unless specifically agreed to by the cognizant test article engineer and the guard escorts the person while he is performing his function.

4.10.5 Fire Fighting

Persons not trained in fire fighting s hall use their best judgment in attempting to fight fires. The quick use of local hand fire extinguishers may prevent progression into a major fire and should be the first action taken if it is absolutely clear that the fire can be extinguished quickly and effectively. Whenever possible, only Halon 1301 or 1211 hand-held extinguishers shall be used. Help shall be summoned immediately, even if the fire has been extinguished. If two or more persons are available, at least one shall summon help immediately. Personnel shall evacuate the area immediately if the fire is near or involving ordnance (see Section 4.2.10.11.3). Refer to Section 4.4.4 for facility fire protection requirements, including facility contents notification.

4.10.6 Area Access

Personnel access to areas involved in JCI activities at all levels of fabrication, handling, transport, assembly, test and operations, and launch support shall be controlled. Only those persons whose assigned duties and functions require repeated attendance in the area shall be permitted regular access. Observer access shall be kept to a minimum. The controls shall be appropriate for the specific equipment and activity involved (see Section 4.10.4).

4.10.6.1 *Fabrication Areas*:. Personnel access to fabrication areas shall be controlled if the materials or processes are hazardous to personnel, or if the presence of too many persons is potentially hazardous to the process.

4.10.6.2 *Test and Operations Areas:* Personnel access to JCI assembly, test, and operations areas shall be controlled by the test agency. Controlled areas may include support equipment and analysis team areas to minimize the potential for distractions and other hazards that can be caused by well-meaning observers.

4.10.6.3 *Launch Areas:* Access to facilities at launch areas is generally controlled by the launch agency. Facilities for hazardous activities, typically referred to as Hazardous Processing Facilities (HPF) are usually controlled by a security guard, and the number of persons in the area at any given time is restricted. Access to these areas shall be approved by the JPL Station Manager (or equivalent responsible person) and by the launch agency. In general, safety courses, physical medical exams and citizenship and badging requirements must be complied with prior to launch site activities. These requirements are usually coordinated through the Project Ground Operations Manager.

4.10.6.4 *Oxygen-Deficient Areas:* Areas that could become deficient in life-support oxygen and result in asphyxiation shall be posted with warning signs. Examples of these areas include rooms and areas in which gaseous purges (nitrogen, argon, helium, etc.) are venting and areas in which pneumatic-control equipment is located. Rooms in which liquid nitrogen is used are particularly susceptible.

Confirmed areas in which the atmosphere is intentionally or unintentionally depleted of oxygen shall be verified safe for personnel prior to personnel entry into the area. These areas include vacuum chambers, rooms intentionally purged with nitrogen or other inert gas, and sublevel sumps or wells (pits) which do not have good natural air flow. Oxygen monitors shall be in valid calibration, available and utilized. Personnel working in these areas shall be specifically informed by the Cognizant Supervisor of the area of the proper responses for aiding disabled victims in such areas. Confined areas must have a permit in accordance with local CAL/OSHA and OSHA requirements. For JPL, the Safety Operations Section and the JPL Fire Department should be consulted.

4.11 LAUNCH SITE OPERATIONS

Pre and Post Launch site operations are an extension of the Spacecraft, Instrument or Experiment assembly and test operations performed prior to transportation to the launch area. A Facility Safety Survey (see paragraph 4.9.1 of this document) conducted at the launch site complex will identify potential hazards. These can be mitigated to the satisfaction of the launch site agency, the Systems Safety Engineer and the Project Manager.

Previous requirements shall apply to the activities in the launch site area in addition to the following specific requirements.

4.11.1 Responsibilities

4.11.1.1 General*:* The overall responsibility for personnel and hardware safety during operations at launch site areas is vested in the Section Manager and in the Project Element Manager responsible for the overall activity as specified in Section 1.2.2. The responsible Manager may delegate authority for carrying-out specific actions involving safety to on-site personnel. Such delegation in no way relieves the Manager of the responsibility for such actions.

At the Eastern Range (ER)[which includes both the Cape Canaveral Air Station (CCAS) and the Kennedy Space Center], activities involving safety shall be coordinated through the JPL Station Manager located at the KSC unless other communication channels are specified and agreed to by all involved Section Managers.

The Project assigned launch site (range) safety managers shall function in accordance with appropriate protocol instructions and procedures required by the launch area documents listed in Section 4.11.2.

Individual area responsibilities may be assigned to cognizant persons for activities in those areas, but the safety responsibility cannot be delegated.

The Systems Safety Office shall be notified of all hazardous operations planned for launch site areas and shall be responsible for ensuring that proper interfacing between the responsible JPL personnel and the appropriate launch complex safety personnel is accomplished (see Section 1.2.2.2).

4.11.1.2 *Supervisory Responsibilities:* The following specific responsibilities for supervisory personnel include, but are not limited to:

(1) Ensuring that written and approved procedures are used for all operations of a hazardous nature.

(2) Stopping any operation that appears to be unsafe, or is not being conducted according to written and approved procedures.

(3) Controlling personnel access into the area.

(4) Ensuring that required warning devices indicate the proper condition of the activity.

(5) Ensuring that all personnel in the area are properly informed of the status of operations affecting the hazard status of the area.

(6) Informing and advising all personnel in the area of abnormal incidents and the necessary action to be taken.

4.11.1.3 *Individual Responsibilities:* Personnel are responsible for:

(1) Performing assigned functions in a safe manner in accordance with established procedures .

(2) Familiarizing themselves with the rules and procedures governing their portion of the operation.

(3) Reporting promptly to the area supervisor or cognizant en gineer any unsafe condition that may be detected.

(4) Familiarizing themselves with the physical layout of the area, especially noting locations of emergency exits, warning or caution signs, alarms, fire fighting equipment, emergency breathing apparatus, and other safety equipment in the area.

4.11.2 Launch Site Area Requirements

The launch Site area requirements are too numerous and detailed to include in this document. Specific documents applicable to selected launch site complexes are listed below.

Cognizant Engineers of equipment having safety related concerns, are responsible for complying with the appropriate sections of these controlling documents.

S-100	KSC Kennedy Space Center	KHB 1700.7/ 45 SPW HB (STS Payloads) KHB 1710.2 (All Payloads)
	Eastern and Western Range Safety Requirements	EWR 127-1 (ELV Payloads)
	CSG Center Spatial Guyanais	RS-CSG-Ed (0)

4.11.2.1 *Safety Assessment Report Requirements:* The Project/Program Safety Assessment Report may be identified in several ways, depending upon the launch agency, location and method of launch. E.g. STS launches from KSC list the Safety Data Package as a phased Safety Assessment Report, expendable launches using the Air Force facilities at ER (Florida) require a Missile System Pre-launch Safety Package (MSPSP). Insofar as a name is concerned, the Safety Compliance Data Package will contain, essentially, the same safety identification, controls, verification and qualification necessary for permission to launch.

Detailed information for all hazardous items shall be included in the phased assessment reports to be submitted to the launch area and/or launch vehicle safety organization(s). The information contained in the SAR/Missile System Pre-launch Safety Package shall include, but not be limited to, detailed descriptions of each of the following hazardous subsystems and of each hazardous item contained therein:

(1) Propellants and propulsion subsystems.

(2) Ordnance subsystems.

(3) Electrical and electronic subsystems (includes batteries).

(4) Pressurized subsystems and components (includes heat pipes, cryo-cooler/compressors, purge units).

(5) Nonionizing radiation subsystems.

(6) Ionizing radiation subsystems.

(7) Structural and mechanical subsystems.

(8) Acoustical subsystems.

(9) Hazardous materials.

(10) Hazardous commands or stimuli.

(11) Any other hazardous subsystems.

The above list is typical of the data required in a Safety Compliance Data Package. The format requirements for the package vary from one launch agency to another. These requirements (for format as well as content) can be found in the individual launch agency requirements documents, including EWR 127-1, MIL-STD-882, NSTS 13830, KHB1710.2, NSTS 1700.7, KHB 1700.7, RS-CSG-ED (O) or EHB-0004.

4.11.2.2 *Safety Compliance Data Package Responsibilities:* The Project Office/Cognizant or Project Element Engineer for the hazardous items shall be responsible for the submission of the safety data and control verification information to the responsible Systems Safety Engineer.

The SSO Engineer shall be responsible for, compilation, submission, presentation and review of the information to the respective launch agency safety organization.

4.11.2.3 *Requirements Document:* The Program Requirements Document (PRD) is prepared and maintained by the launch agency with inputs from the Range/KSC/Launch Complex user. It contains a listing of all the launch agency support, services and equipment needed by the project during pre-launch and launch operations. Support required for hazardous items shall be kept up-to-date and shall be provided to the launch agency by the Project Office.

4.11.3 Typical Launch Site Area Safety Requirements

4.11.3.1 *General:* The following general requirements shall be followed by all personnel involved in activities with JPL flight hardware at the launch area. These rules shall be followed even if the launch site area or facility does not require them.

(1) Flammable or highly reactive materials, such as gasoline, solvents, highly corrosive acids, bases, etc., shall NOT be used in the JCI working area without specific approval from the JPL Systems Safety Office, the spacecraft materials engineer, and the Facility Manager. This includes isopropyl or ethyl alcohol used to clean hardware.

(2) Precautions shall be taken to prevent the generation, and to promote the continuous dissipation, of static electricity , before it reaches a hazardous level. This includes personnel and hardware.

4.11.3.2 *Ordnance or Propellant Loading:* When hazardous materials such as ordnance or propellants are in the vicinity or on board the JCI, the following rules shall be observed:

(1) Operations involving heat-producing mechanical work that may elevate the temperature, impact, or produce shock on any

ordnance item or propulsion subsystem shall NOT be permitted. This includes hammering, drilling, grinding, wire brushing, etc. Soldering irons may be used only if specific approval from the JPL Systems Safety Office and from the host organization's safety office is obtained each time the equipment is to be used.

(2) Buildings containing a hazard shall be properly placarded to show the danger level and the classification of the hazard.

(3) Warning devices, such as road blocks or flashing lights, indicating hazardous conditions or activities within the facility shall be activated to indicate the appropriate condition.

(4) Safety equipment, such as showers and eye washes, shall be verified to be in good operating condition prior to the start of any hazardous operation, or prior to locating hazardous equipment in a facility.

(5) Powered electrical equipment shall be of an approved hazard-proof design and shall have a "third wire" ground if externally powered. This includes facility lighting, outlets, power distribution extension boxes (that are fused), switches, and conduits within the hazardous area.

(6) The condition and configuration of hazardous material disposal containers or sumps shall be verified prior to initiation of any hazardous activity that may require them.

(7) Incompatible materials (such as fuel and oxidizer) in non-flight containers shall not be in the same room or building area at the same time.

(8) Nonessential personnel shall be cleared from the route of travel when a loaded or pressurized JCI, including GSE, is being transported.

(9) Unnecessary combustible material shall be cleared from the area prior to starting any propellant or ordnance operation.

(10) Persons involved in a hazardous operation shall be suitably clothed as required by the host safety organization. Such protective clothing or equipment shall be approved by both the JPL Systems Safety Office and the host organization safety office.

(11) The buddy system shall be observed when handling hazardous materials.

(12) Appropriate equipment shall be available for containing and/or flushing spilled hazardous materials .

(13) Personnel shall be properly certified and qualified for the specific hazardous activity.

(14) Safety instructions issued by any cognizant safety officer or representative shall be obeyed by all personnel immediately. Discussions relative to the resumption of activities can then be carried out after a safe operation and facility situation has been established.

4.11.3.3 *Radiation:* Activities and operations at launch site areas involving ionizing radiation shall be performed under the cognizance of the JPL and the launch area Radiation Safety Officers. The source and area control requirements of the JPL Safety Manual (4-08-50 through 4-08-57) shall be implemented. In the event of a conflict between the JPL Safety Manual and the launch area requirements, the more conservative (safer) requirement shall prevail.

4.11.3.4 *Launch Site Safety Plan: A* launch site (complex) safety plan shall be compiled and submitted to the Launch Agency (or Launch Agency Customer) by the Project System Safety Engineer. The plan will describe the composition and organization of the Project launch complex support team, as well as all procedures for transportation, lifting, servicing and testing of the Instrument at the launch site. The plan should be submitted to the Launch Site Safety Officer prior to the commencement of ground operations (generally six months prior to launch.

5 GLOSSARY

AC	Alternating Current
Ah	Ampere-hour
AHSE	Assembly and Handling Support Equipment
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing Materials
BBL	Burst Before Leak
BoE	Bureau of Explosives
C	Centigrade
$C0_2$	Carbon Dioxide
CAL OSHA	California Occupational Safety and Health Administration
CCAS	Cape Canaveral Air Station
CDRL	Contract Data Requirements List
CFC	Chlorofluorohydrocarbon
CFR	Code of Federal Regulations
Cm	centimeter
$COCl_2$	Phosgene
COPV	Composite Overwrap Pressure Vessels
COSPAR	Committee on Space Research
CSG	Guiana Space Center
dB	decibel
DIS	DMIE Information System
DM	Design Manual
DMIE	Define and Maintain Institutional Environment
DNP	Develop New Products
DNT	Develop New Technology
DoD	Department of Defense
DoT	Department of Transportation
DRD	Data Requirement Description
DSN	Deep Space Network
ECR	Engineering Change Request
EGSE	Electrical/Electronic Ground Support Equipment
ELV	Expendable Launch Vehicle
EMI	Electro-Magnetic Interference
ER	Eastern Range
ERT	Emergency Response Team
ES	Equipment Specification
ESD	Electrostatic Discharge
ETL	Environmental Test Laboratory
ETR	Eastern Test Range
EVA	Extra Vehicular Activity
EWR	Eastern/Western Range
F	Fahrenheit

FED STD	Federal Standard
FS	Factor of Safety
FSS	Facility Safety Survey
Fy/Fu	Ratio of yield strength to ultimate strength
GHB	Goddard Hand Book
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
H_2	Hydrogen
HFC	Hydrofluorocarbon
HPF	Hazardous Processing Facility
ICC	Interstate Commerce Commission
IATA	International Air Transport Association
IEC	International Electrotechnical Commission
IR	Inspection Report
JCI	JPL Critical Item
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
Kg	Kilogram
KHB	Kennedy Hand Book
KPa	kilo Pascal
KSC	Kennedy Space Center
LAE	Launch Approval Engineering
LAPPG	Launch Approval and Policy Planning Group
Lb	Pound
LBB	Leak Before Burst
LH_2	Liquid Hydrogen
LHe	Liquid Helium
LN_2	Liquid Nitrogen
LOX	Liquid Oxygen
LSO	Laser Safety Officer
MAM	Mission Assurance Manager
MAWP	Maximum Allowable Working Pressure
MDOP	Maximum Design Operating Pressure
MDP	Maximum Design Pressure
MEOP	Maximum Expected Operating Pressure
MGSE	Mechanical Ground Support Equipment
MIL-HDBK	Military Hand book
MIL-STD	Military Standard
Mm	Millimeter
MMH	Monomethylhydrazine
MOP	Maximum Operating Pressure
MPa	Mega pascal
MPH	Miles Per Hour
MRB	Material Review Board
mrem	milli roentgen equivalent man
MS	Margin of Safety
MSDS	Material Safety Data Sheet
MSFC	Marshall Space Flight Canter

MSPSP	Missile System Pre-launch Safety Package
MUA	Materials Usage Agreement
mW/cm2	milliWatt per square centimeter
MWP	Maximum Working Pressure
N_2H_4	Anhydrous Hydrazine
N_2O_4	Nitrogen Tetroxide
NASA	National Aeronautics and Space Administration
NCR	Nonconformance Report
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Test
NEC	National Electric Code
NEI	Non-Explosive Initiator
NFPA	National Fire Protection Agency
NHB	NASA Hand Book
NMI	NASA Management Instruction
NPD	NASA Policy Document
NPG	NASA Program Guide
NPG	NASA Procedures and Guidelines
NSI	NASA Standard Initiator
NSSS	NASA Software Safety Standard
NSS	NASA Safety Standard
NSTS	National Space Transportation System
OSR	Operational Safety Review
OSS	Operations Safety Survey
P/FR	Problem/Failure Report
PDR	Preliminary Design Review
PEM	Project Element Manager
PF	Proof Factor
PRD	Program Requirements Document
Psi	Pounds per square inch
Psig	pounds per square inch, gauge
QA	Quality Assurance
RF	Radio Frequency
RFP	Request for Proposal
RMS	Root Mean Square
RSC	Radiation Safety Committee
RSO	Radiation Safety Officer
RTG	Radioisotope Thermal Generator
SAM-RC	Structures and Materials Review Committee
SAR	Safety Assessment Report
SFOF	Space Flight Operations Facility
SHA	Software Hazard Analysis
SP	Safety Practice
SPEC	Specification
SPI	Standard Practice Instruction
SSC	Safety Steering Committee
SSCF	Software Safety Critical Functions
SSE	Systems Safety Engineer

SSO	Systems Safety Office
STS	Space Transportation System
STS/ISS	Space Transportation System/International Space Station
TBD	To Be Determined
TLV	Threshold Limit Value
TML	Total Mass Loss
TO	Technical Order
TSS	Transportation Safety Survey
UL	Underwriters Laboratory
VAC	Volts Alternating Current
VDC	Volts Direct Current
WR	Western Range
WTR	Western Test Range